VOLUME 4, NO.2, JULY, 2013 & VOLUME 5, NO.1, JANUARY, 2014

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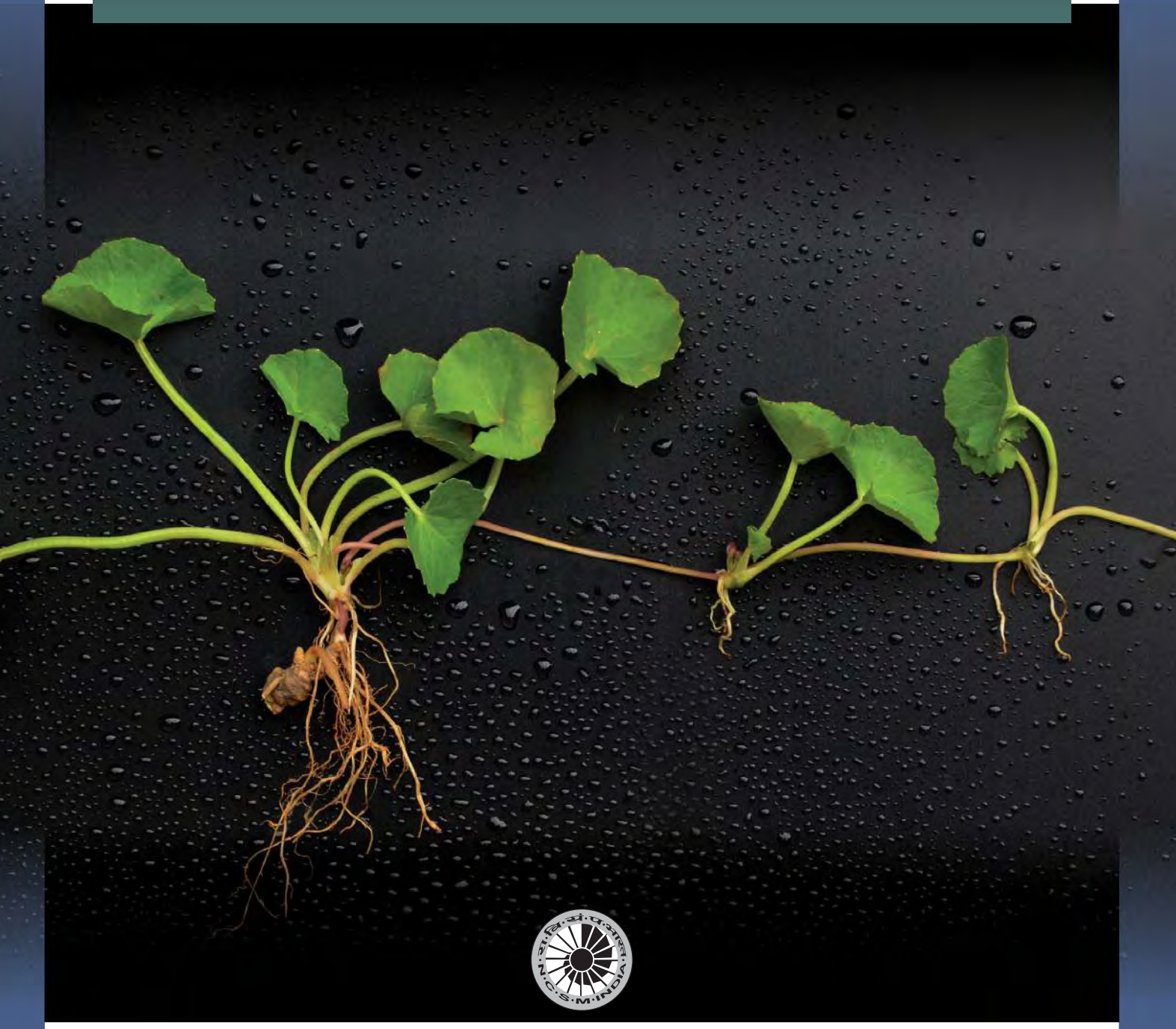
A Journal of Science Communication



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Editorial

Nothing could possibly be as disconcerting as penning the editorial of a belated publication. Regrets and apologies do not compensate for the loss of time, yet that is exactly what I humbly tender before our readers. On the brighter side, this combined issue brings a variety of articles from a wide cross section of authors from diverse backgrounds and experience, which I believe our readers will find interesting.

The article 'Leonardian Dream : Tempting Completeness by a Special Interweaving of Art and Science' breaks the barrier between arts and science while discussing the contribution of famous Hungarian artists who utilized the laws of optics and created innovative and intricate artistic presentations that were recently exhibited in the Indian network of the National Gallery of Modern Arts in Bangalore, Delhi and Mumbai under the title 'From Organic Forms to Light Art'. The article exemplifies the idea that light not only makes objects visible, but it also creates art in a direct way.

The authors of the article 'Electromagnetic Radiation from Mobile Phone and its Effects on Human Brain' discuss the results of their study on the subject and urges the users to be careful about the radiation hazards from the use of cell phones.

The trajectory of the initial deleopmental phase of Indian science museums and planetariums is interestingly captured in an interview with one of the pioneers on the field in the article 'Beginning of Science Museums and Planetariums in India – Contribution of Ramanatha Subramanian'.

'Planetarium at Calicut - Malabar's Astronomy Hub' narrates the story of the evolution of the Calicut planetarium highlighting the technological challenges faced in the process and how those were overcome successfully.

'Social Inclusiveness of Indian Science Centres and Museums: a snapshot through case studies' is the concluding part of a sequel that deals with the financial aspects of inclusion issues in the Indian science museums and centres.

'Presenting abstract ideas in Science Museums/Centres: Mathematics Gallery of BITM, Kolkata : A Case Study' provides a brief overview of the exhibits in the gallery and explains how various abstract mathematical concepts are explained through interactive models and hands-on activities to help young learners enjoy mathematics in a playful manner and appreciate its inner order and beauty.

In the article 'Science in the Baburnama: A Critical Study', the author highlights how Babur painstakingly and minutely recorded the flora and fauna, wildlife, socio-economic conditions, demographic scenario, land and rivers, climatic conditions etc. of India in the 15th and 16th century.

The article ' A Century of Crystallography' profiles a brief history of crystallography and highlights some of the important applications of crystallography in our life and in addressing development issues such as food security, safe drinking water, health care, sustainable energy and environmental mitigation.

The article 'Design and Fabrication of a Universal Robotic Arm' communicates the result of students' research work towards developing a versatile and low cost robotic arm for industrial applications such as welding, cutting, painting etc. with high accuracy.

'Studying the Anthropogenic Impacts on Coastal Ecosystem of Digha: A Hands-on Approach' focuses on a much argued issue of Digha's costal ecostem degradation due to human interventions and how the local student community is being engaged in hands-on field activities for a better appreciation and understanding of the problem.

'Thermochromic Property of Dichromate in Liquid Nitrogen' presents some interesting findings related to reversible colour change in ammonium dichromate crystals in liquid nitrogen temperature.

I hope our readers will find the articles interesting and informative.

E Islam
Chief Editor

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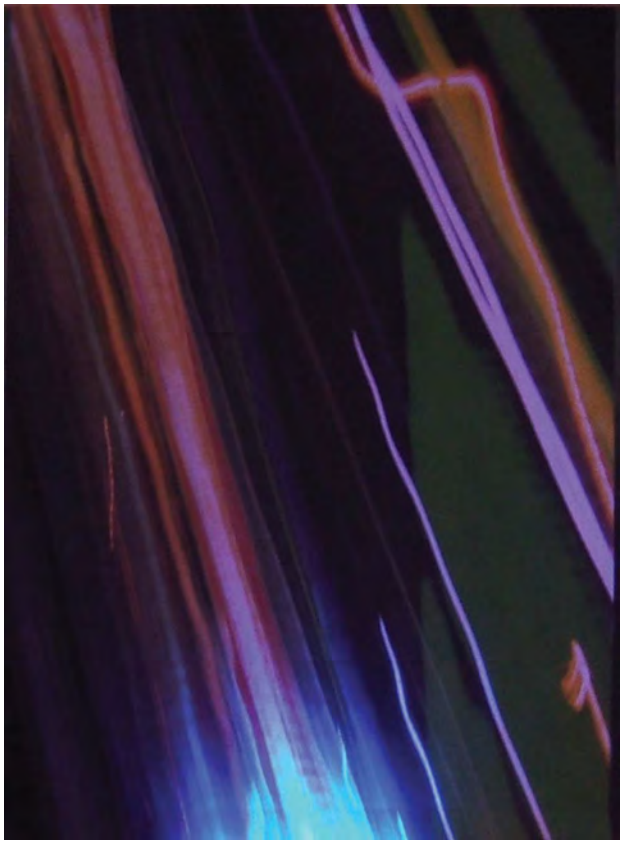
The Leonardian Dream : Tempting Completeness by a Special Interweaving of Art and Science

Attila Csáji

Within the Hungarian-Indian cultural cooperation, a series of exhibitions were realized in the recent past, at the network of the National Gallery of Modern Arts, in Bangalore, Delhi and Mumbai, which wore the following title: 'From Organic Forms to Light Art' (a selection of contemporary Hungarian art). Organic forms imply the nature and the need of integrity; 'light art' as a definition is unusual, it stops you and makes you think. Light is the basic cause of visibility – at the fine arts it is indispensable. It is an integral part of everyday life, but something else also resides within it. It is one of the greatest human experiences – it radiates devotion or even adoration, purification and ascension. It is a research subject for scientists and it can create an elevating sacral experience at the same time. But does the light not only make the objects visible but also create art in a direct way ? The light experiences of nature suggest such since ancient times.



LászlóMoholy Nagy – one of the determining masters of the Bauhaus school, which had a serious impact on the art of the 20th century (Weimar, Dessau) – announced with prophetic enthusiasm in the 1920-30s that most of the future works of art will be the task of light-painters. Following his footsteps another Hungarian artist, György Kepes, who was the head of the light department in the New Bauhaus in Chicago, created the first research institute, the Center for Advanced Visual Studies, at the Massachusetts Institute of Technology, in Cambridge, in 1967, in which artists, scientists and technologists could work together on new medial researches. The institute has become exemplary in the world since then. The idea of László Moholy Nagy sprouted, but it was the opto-electronic revolution that meant the most serious impulse, that has been rewriting also our daily lives in the past decades. This system of tools (the laser, the computers, the holography, etc.) compares with the tools of the time of Moholy Nagy as a magnifying glass to an electron microscope. The artistic utilization and humanization of the system of tools created by the modern science and technology is one of the prominent tasks of the contemporary art.

The International Kepes Society regards this as a primary mission – 14 members of the society, of course the Hungarians, took part in the exhibition series in India. (Éva Bortnyik and Csaba Tubák: light installations; Zoltán Bohus: glass art; Attila Csáji: pictorial possibilities of laser, superposition method, holography; László Haris: conceptual photo; Attila Kovács: geometric structures; Klára Kuchta: UV-sensitive textiles; Ferenc Lantos: geometric painting, analyzing nature, structure building; Ilona Lovas: light installation; Mária Lugossy: glass art; Waldemar Mattis-Teutsch: pixel holography; András Mengyán: surprising dimensional effects created by UV-sensitive paint; anamorphias of István Orosz; plexiglas sculpting of László Paizs.) Our presented artworks are mainly based on the utilization of the contemporary scientific and technical possibilities; they represent one of the dominant threads of the artworks exhibited in the NGMA in Bangalore.

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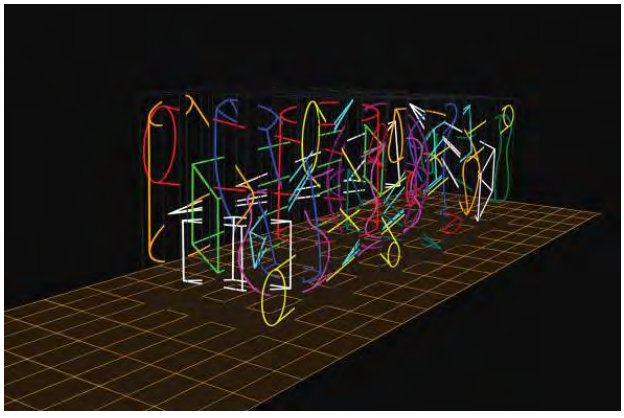
This is the objective side of the background story of the exhibition. There is also a subjective one, which is connected to the curator of the exhibition. In my work organic and light art meets each other, which provides a conceptual basis to the exhibition series realized in the NGMA. Through this, I can present in the strongest way the activity in which art-science-technology are intertwined, and which appeared at the exhibition of the NGMA very markedly. This activity attracted international attention, and I was invited by the Massachusetts Institute of Technology / Center for Advanced Visual Studies on this basis to be a member of the institute. But this only occurred in the second half of the '80s. The path leading to this began decades earlier.



I have been interested in forming images using light since the middle of the sixties. My works titled 'Messages – Sign Grids' - these plastic structures evoking ancient writings and that can be further interpreted by oblique light (also known as side light orindirect light) were the precursors of my light art works – one of which could also be seen in this exhibition series. From the early seventies, I started to use special paints in some of my works. I could further interpret my pictures painted with luminescent powders sensitive to the different wavelengths of electromagnetic radiation (e.g., to 330 or 380 nanometers UV light) with the appropriate light sources. Thus I, in a manner of speaking, mobilized the pictures. I created neon statues in the middle of the seventies. The major change occurred in 1977. Norbert Kroó, Physicist, leader of the laser research in Hungary, attending my exhibition organized in the Hungarian National Gallery, saw how much I am interested in the further development of pictures by light. He invited me to the laboratories of the Central Institute of Physics (Budapest), so that I could continue my experiments by a well-maneuverable light source, the laser. I came into intimate contact with the modern optics here. With Norbert Kroó, we established a research group in the Institute, the 'PHOTON ART', which was responsible for the exploration of the pictorial possibilities of the laser light.

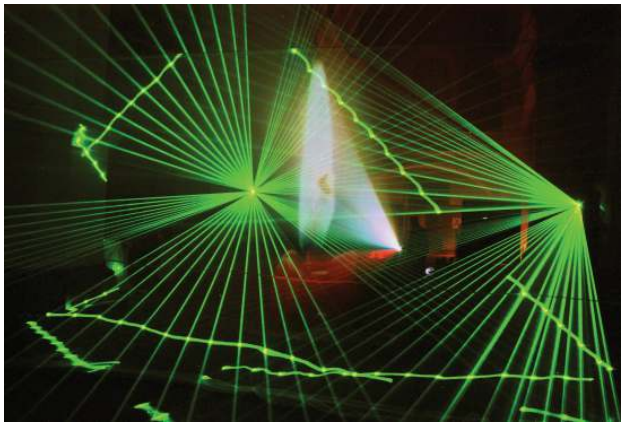
As the leader of the group, I specified the basic objective - the characteristics of the laser light from the painter's point of view. It is may be more accurate if I say that these should be approached from the viewpoint of an artist working with the visual possibilities. While, for instance, discovering the characteristics of the marble has a thousand years of living experience and a lot of things can be taken over from the masters, the laser light was almost a virgin area for an artist in the seventies.

The three basic characteristics of the laser light are the following :

1. The high degree of maneuverability;
2. The high brightness concentrated to one point;
3. The high degree orderliness and monochromatic nature of the laser light, and its interference ability resulting from this.

These involve different pictorial possibilities. Let's take these characteristics of light one by one. From the concentrability to a single point came the drawing by

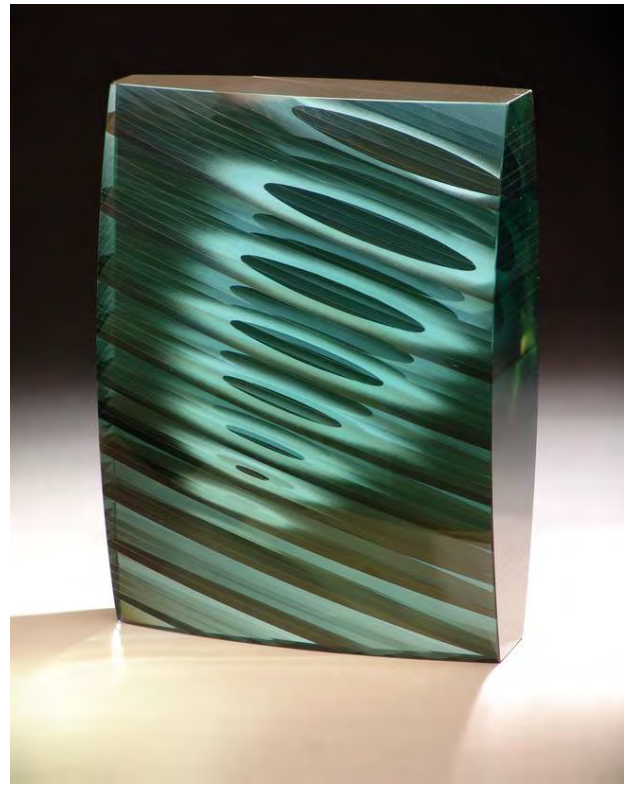
scanner, which can be realized with the help of swinging mirrors moving on the x and y axes, controlled by electronics and computer. In the United States, besides holography, they concentrated mainly on this, and reached excellent results. For this, swinging mirrors with special frequency, eliminating post movements, were necessary – but at the end of the seventies, these were on the so-called 'COCOM' list – thus in the so-called socialist countries they were unattainable. This also contributed to the fact that in our researches we concentrated on the third light characteristic of the laser, the monochromaticness. At the end of the seventies they regarded interferences as a physical phenomenon, which is not moldable by the artist and is not manipulable.



At the start of the analyses I regarded my primary task is to reveal the pictorial chaos of the meeting of the light waves which appeared random, to establish order, to find the most usable motifs and the tools and correlation of conscious manipulation. At the beginning, we developed hundreds of photos necessary for the analyses – marking the diameter of the laser light used, illumination, transparent, plastical surface and the generated interference light shape. One of the first things learnt was that the generated light shapes have no depth of focus, thus it can be captured on different geometric surfaces, light environment can be created and it can even be projected on the human body.

The second: as a consequence of the analyses, I could slowly come to regard the surface forms as codes, that, when displayed by laser light create given interference characters.

The third led – indirectly – to the furthest. The forms are realized in a so-called Fourier cone. The apex of the cone is on the illuminated crystal clear transparent disc, and moving away from this – defined by the aperture of the cone – the resulting light shape gets bigger and bigger. I tried to manipulate this with different optical devices.



During the experiments such possibilities for further interpreting the view arose before me, which made the realization of a new image alteration method – the so-called superposition transformation mode – possible (International Patent 1980). The essence of the method is the flexibility of optical devices placed at the appropriate location on the optical car compared to the media disc (patent), and that it is based on interferences. The novelty of the view is realized by the superpositions and for its display coherent light is indispensable. The motif recorded on the so-called image-disc can be further interpreted with classical optical devices inserted at the appropriate place. In the resulting picture are the modeled real micro-motif (mask, human head, braided ribbon, etc.) and its Fourier transform and the related multitude of interference pictures can all be observed.

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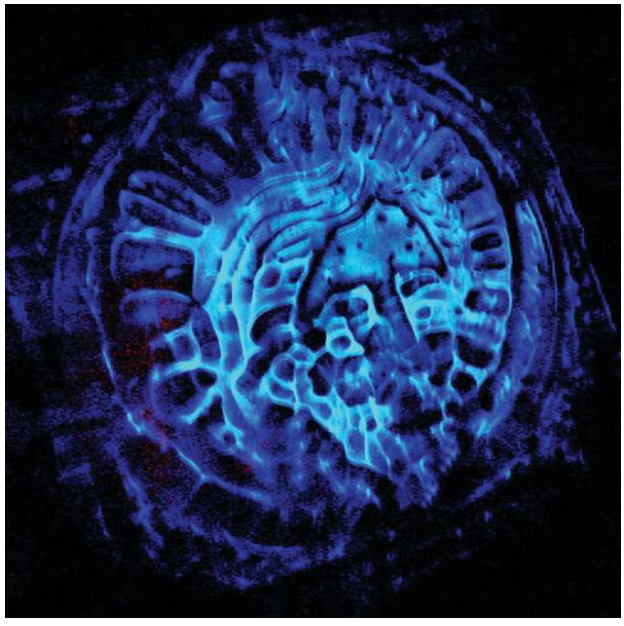
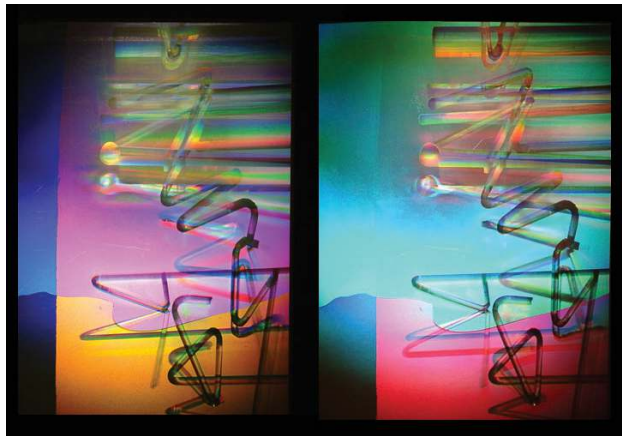


Their proportion in the metamorphic development of the process is variable. The largest opportunity in this method is the possibility of making visible the connecting bridge between expressivity and regularity. The organic and continuous pictorial changes create the transitions between the world observable with our eyes without auxiliary aids and the mathematically, precisely describable laser interferences. This process brought an unparalleled richness of the forms that can be created only by laser. (English language informative article: Leonardo 1992/1.) Inherent to the visual thinking in this method is concentrating on the metamorphic processes, the timeliness resulting from this, creating environment by light, multimedia, and acquiring such knowledge that have interdisciplinary nature. Also at the MIT, which is perhaps the most important global center of the medial research, this method was regarded as unique, and Paul Earls introduced me as a breaker of virgin lands. My laser animation film presented at the Bangalore exhibition, the '6th or the 7th' (Budapest, Pannonia Film Studio, 1982-83) is built on this superposition method.

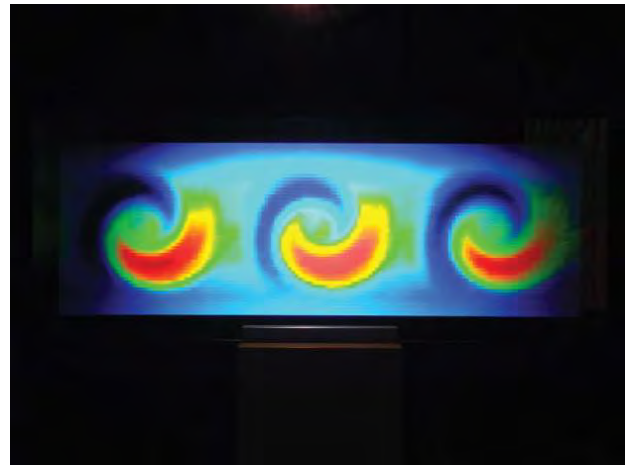
The making of the film was also a groundbreaking undertaking. It was presented at several places: in the Hungarian National Gallery, in the German Film Museum in Frankfurt am Main – on the occasion of the first holographic World Exhibition, where holography was introduced as a new artistic media; at the Museum of Modern Arts in Paris, on the occasion of the exhibition titled ELEKTRA, where those artists were presented who can be classified as innovators of the artistic use of electricity; at the Massachusetts Institute of Technology in Cambridge; at the Oberhausen Film Festival, in London, in New York, etc. In India it was an integral part of the exhibition titled 'From Organic Forms to Light Art' – and during the exhibition it was projected continuously. Dynamic metamorphosis is the defining experience of forms of the film. At the same time it is a visual paradox, which creates strange correspondences between the microcosm and macrocosm: cells are formed from the star clusters, and infinite space from crystals. The instruments which are unavoidable in our civilization become the servers of the artist's thinking, and create a world which is continuously expanding in vision as well as around us. In the film the superposition method becomes the source of new sensory experience and harmony.

From the coherence of laser light derives its *holographic* use, as well. The first hologram was created by Denise Gabor Hungarian physicist even before the invention of the lasers. The lasers provided significant opportunity for the holography, as well. Holography today has several types: reflection holograms, transmission holograms, multiplex holograms, shadow grams, rainbow holograms, etc. In the exhibition you could find the transmission hologram, the reflection hologram, the pixel hologram and a special variety of the rainbow hologram. Within holography I was primarily interested in what are those pictorial opportunities which are only made possible by the instruments of holography, which only exist virtually,



but can be made reality through holograms. Such as the levitation of mass, the transparency of masses, questioning the evidences of spatial perception, creating color changing structures within the picture, etc. – with which the perceivable-visible world can be further created. Of the artworks displayed in the NGMA the light calligraphies (transmission hologram) – whose inner color structures are mobilized by the movements of the viewer – belong to this. These holograms are part of a series and relate to the Sign Grids created in the sixties that are also calligraphic. Here I was primarily interested in the plastical structures which, could be shaped by side light, in a monochrome world of colors – but here colors became strong, heightened and I was more interested in a liberated, mobilized, but still harmonized color scheme rather than plasticity. In the case of my hologram titled 'Light Source' color permutation appears, with the changing of the colors of the pictorial information arranged in rows (blue-violet, orange, etc. dominance – in an associative aspect with the change of the lights-colors the night-day, etc.). Its essential content, however, is deeper. I was asked to create this hologram for the 100th anniversary of the Budapest Museum of Fine Arts – thus it is primarily an 'honor to the guardians, the guardians of inner light'. Its essence is the beyond-avant-garde formulation of a classical idea. The Museum for me is not dead, I regard it as a source of light, which is an accumulation of inner light – and it radiates this fertilizing light to those who are receptive for it. The title of the hologram, the 'Light Source' also derives from this.

The large pixel hologram of Waldemár Mattis Teutsch, the 'Maeltstrom' belongs to the category of the so-called pixel holograms. The beginning of these is created on computer. It has no depth of field – but it still occurs from the spatial indicator role of the colors, as blue is located in another segment than, let's say, the yellow or the orange. Its visual default value is built on this. The creator establishes a formally defined, starting color structure (wave crest vortex), which affixes on a holographic emulsion layer, and by the change of position of the viewer, it effects a change in the color structure in the order of the colors of the rainbow. It is highly decorative and its size can be increased substantially – thus it is suitable for holographic covering of even walls of buildings. It is one of the most impressive pieces of the exhibition – this is why I



consistently placed it in a way to influence the basic experience of the entering person.

The other determining spectacle of the light art section of the 'From Organic Forms to Light Art' exhibition is derived from the *phenomenon of luminescence,* the use of *paints sensitive to ultraviolet light.* The large size textile of Klára Kuchta that can be hanged on the wall and the pictures of András Mengyán belong here.

In the exhibition four paintings of András Mengyán, created with paints sensitive to ultraviolet, light can be seen. They are strongly reductive, restrained, rational pictures. They belong to the constructivist line which has extraordinarily strong traditions in Hungary since Lajos Kassák and László Moholy Nagy, and to which the sensitive geometric line rhythms of Tamás Konok, the system building geometry of Attila Kovács and the works of the excellent teacher, Ferenc Lantos also belong. Mengyán just partly belongs here; he overgrows this tradition, and creates an unmistakable individual path.

What does this individual way consist of ? It is mainly of the electroluminescence, the differentiated and resourceful use of the phenomenon of photoluminescence and its characteristic geometric structures. One of his typical methods is replacing, sequence changing. His systematic nature, the consistency of his thinking, the in-depth analysis which is his essential feature are all taking him towards thinking in pictorial processes. This way of thinking implies the need to break through the closed structures, a more complex world view, which carries within itself

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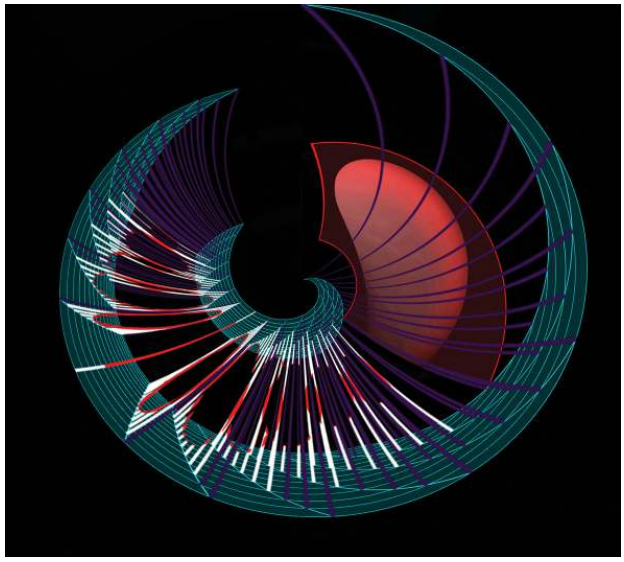
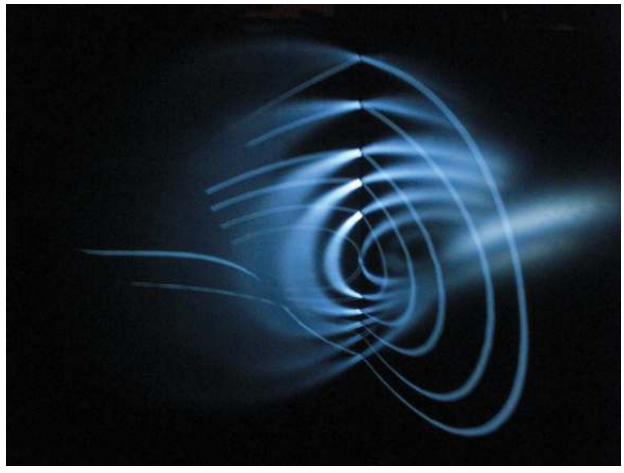


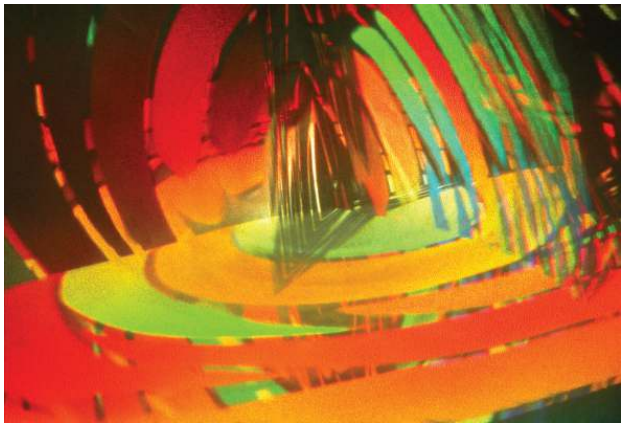
simultaneity – synchronism – and the possibility of development of forms within the time processes. It recognizes that depending on the light conditions, the interpretation of the pictures can be different. The plane is divided differently by the lines, curves and shapes created by the specially activated paint sensitive to photoluminescence, than by the ones made with common pigment paint. Spaces, symmetries and dimensions with a character that is different from the known geometric structures can be created by them. With the aid of the so-called 'black light' at places its colors become aggressive and vivid, often they appear from a black background – this way also enhancing the assertion of the luminescence. As we know, luminescence is the light emission accompanying the spontaneous return of the electrons from their excited state to their base state. These luminescent colors have different saturation and sensible intensity than of the colors before the excited state. We can experience with the pictures of András Mengyán that the different combinations of the 'lucenera', the black light and the UV active materials in the consciously developed structures can create magical light effects. All this he creates with impressive intensity and consistency. The life work of András Mengyán is an outstanding achievement even measured on the standard of international light art.

The third unit of the light art section consists of the light installations. In the case of an installation, the visual experience usually derives from the interaction of the devices used – the interaction of the medium (here: video) used and the object – set of objects – on which the projection happens. In the case of the artist duo Éva Bortnyik and Csaba Tubák (husband and wife) it is a V shaped object painted black, with dull light. The planeness of the projected surface disappears by the V shape. The world of forms evoking Op Art is projected on them. The metamorphic changes of geometric forms shaping with orderly, but still liberated playfulness consciously enhance the spatial experience. This is also further increased by the particular quality and slight reflectiveness of the special black paint used.



In case of the installation of Ilona Lovas, we can see a double video image projected next to each other. It is a special memorial to her master hat-maker grandfather. On huge surfaces touching each other water is fluctuating silently – radiating the calmness of infinity –, hat shapes made of wood are swimming-floating on them.

In the work of Zoltán Bohus, the interconnection between the knowledge of light art, industrial technologies and the constructivist way of thinking occurs. It was an excellent idea to put his work on the invitation card of the exhibition in Bangalore. He is one of the outstanding personalities of the international glass art. He is the groundbreaker of the glued-layered glass, the so-called cold processing. With him the transparent-translucent material and the symbolic interpretation of light are in harmony with the strict adherence to the optical laws. He is constructivist and lyric at the same time. In his works, in the relation of the glass and the light, resides the connection of time and infinity.

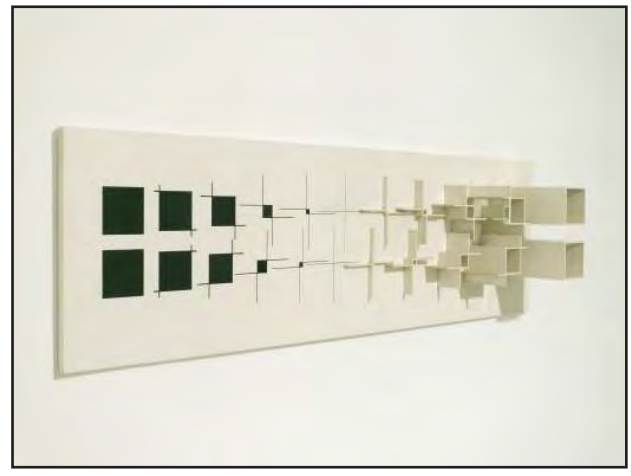


In his works, Ferenc Lantos repeatedly highlights the mathematical laws recognized in organic forms (e.g., the Fibonacci series or the golden ratio). He developed an excellent visual education system, which builds on the discovery, exploration and creative familiarization with the autonomous visual language.

Attila Kovács has been dealing for decades with the drafting of a new non-figurative synthetic visual language, one that can be programmed with the informational logic of yes and no. The aim of his art is changing the given visual qualities into different visual qualities. His starting point is the non-Euclidean mathematics of János Bólyai and the visual aesthetic information theory of Max Bense.

Tamás Konok is the third geometric painter who partakes in the exhibition. In his case, I quote from the author himself : 'My line structures are the harmonies of my thinking process. It is an interconnecting system, which refers to the infinity beyond the picture. In the past thirty years, I have been ever more drawn to the transcendent feeling of life, which exists regardless of experience, for the presentation of the timelessness, which cannot be comprehended by the mind.'

The anamorphic engravings of István Orosz evoke the classical craftsmanship knowledge of the book illustrations of the 19th century with their lean-linear elaborateness. He associates all this with bizarre geometric transformations. Surprise and humor are also not far from his graphics, which can be interpreted with magical mirrors. Let us think, for example, of his work titled 'Albert and I', which was presented in the exhibition in Bangalore, where the chaotic world of the environment resolves into the head of Einstein in the cylindrical mirror, but if we take away the mirror, the face of the creator, István Orosz, is smiling at us.



László Paizs creates a crystal clear, translucent encompassing form from a typically contemporary material, and lifts the object within it to a different dimension. He hands over the transient pieces of the present – for example, a mousetrap, a coca cola can, the headline of a daily newspaper – to the infinity, encased in crystal clear Plexiglas. He preserves the insignificant, and thus elevates it to a different category. He begins his Plexiglas works at the end of the sixties. He notes even at that time: 'with these objects, I wanted to create conscious fossils'. Artifacts saving from the present - A grotesque mirror to our everyday life.

The title of the conceptual photo of László Haris is a date: 5th June 1975. On the indicated day he took pictures in three-minute intervals of a suburban square from the window of an average house in Budapest. Placing this one after the other, he quasi laid time out to the plane. The photo sequence consisting of 480 pictures follows the events of a single weekday. The 24 hours time process becomes a single picture – the resulting view is a new quality visual reality.

The few thoughts that present the fertilizing interweaving of art-technology-science are mainly based on the Hungarian material displayed in the network of NGMA in Delhi, Mumbai and Bangalore. It is an introduction to the nowadays ever more complex problem of the relations of light art, science and art, and to the visual thinking akin to this. In the last

decades, light became an independent creative medium. Its possibilities are now unfolding and spreading. Light art in many aspects also means the re-thinking of the time-space approach of the artwork.

Light art is such a territory of visuality with inner dynamics that it is not a style or trend of a closed art historical period, but it is a forward-curving combination of new medial possibilities which unfolded in the last decades. Significant catalyzing role was played by the dynamic advancement of opto-electronics for the basic human need to dip the new results of technology and science in the depths of human psyche.

We presented a section from the Hungarian contemporary art here in Bangalore in the National Gallery of Modern Arts, the art of a nation which lives in the center of Europe. The EAST appears again and again in the Hungarians legitimately, if we think of our traditions – which bring us back to the center of Asia. Once an Asian nation, which now lives in the center of Europe. It is due to our Asian past, we have so many outstanding Orientalists. My first master also lived in India, he had good relations with Rabindranath Tagore, and he was the one to invite him to Hungary, where his heart was being healed. But let us also think of the visual link connecting India and Europe, Amrita Sher Gil, who has half Indian and half Hungarian origins. We have just organized an international conference in Budapest of her art – and of the Indian-Hungarian cultural relations, and also a large-scale poster exhibition about Amrita – in consultation with the Indian Ministry of Culture. We have also presented this exhibition in the palace of the UNESCO in Paris – in cooperation. Let me mention that this building, the headquarters of the UNESCO was also designed by a Hungarian architect – Marcell Brauer. The Hungarian Academy of Arts was the main supporter and organizer of both events, and also of the Indian exhibition series, next to the Balassi Institute.

We wanted to give a flash of insight in the Hungarian contemporary art, and within this the light art on the exhibition series titled 'From Organic Forms to Light Art'. Part of this art also lives on in India in Amrita Sher Gil's painting. We show a slice from the contemporary culture of a nation that had significant achievements especially through its scientists and its art. The art of a nation that did not take part in colonization, but was famous by its fights for freedom. A nation that was yet one of the dominant powers of Europe during the middle ages, and it resisted – as a bulwark of Europe – the Ottoman conquest for centuries. It bled out then. But let us skip forward. Let's think of one of the most outstanding events in the 20th century, the revolution of 1956, when it confronted the Soviet Empire almost unarmed, and gave a first, Davidic blow to an ideology that created a terrorist state. The worldwide decay of this ideology began at that point. The bold actions are also inseparable from its art. Let's try to answer the question, from where does it originate ?

One of the basic reasons is the parallel openness to the different tendencies of the Hungarians.

Hungarian culture owes its extraordinary richness mainly to this. It turns at the same time and with almost the same intensity towards the West's – the Euro-Atlantic culture – renewing results – in relation to the exhibition, let's think here of the light art (Bortnyik, Csáji, Kuchta, Mattis Teutsch, Mengyán), of the geometric art (e.g., Konok, Kovács, Lantos), or of the sign-like gesture painting (A. Végh), and towards the East, the existence-stabilizing survival of the view of the ancient cultures – in relation to the exhibited artworks, let's think here of the artworks with an organic view, the buildings and drawings of Imre Makovecz that are almost evoking living beings, the architecture of György Csete, the sculptures of Sándor Csutoros and IstvánIlyés, the sign grid of Csáji evoking ancient writings, but I could continue the line at length.

It is my conviction that this parallel openness to the different tendencies cannot be observed with the same intensity as with the Hungarians in any other nation of Europe. The consequence of this is a spectral richness, which is almost unparalleled. We wanted to indicate this richness with this exhibition. Surreal hybrid creatures at Csíkszentmihályi, full-blooded terracotta in the Minotaur stories of Schrammel, the silence, the meditation, the sea in the works of Tenk, the style of whom is in many aspects akin to the one of Amrita Sher Gil, the super realism in the pictures of Jovián, grotesque social critique in the'boxes' of Péter Prutkay, the irony of the Plexiglas sculptures of László Paizs. Oftentimes this duality is fought within the same person, the same artist (Csáji, Orosz, Stefanovits, etc.).

From time to time those who dream the Leonardian dream again, that the art and the science are not torn apart irrevocably, re and reappear. These thoughts appear in the science and in the art, as well. Kornél Lánczos – this excellent mathematician – writes a study about this with an overwhelming, convincing power, titled 'Science as a Form of Art'. The essence of all basic intellectual activities is the human creating power. Intuition is also indispensable for science; it is not only a privilege of the artists.

The tempting of completeness manifests in this dream. The opto-electronic revolution created a particular relevance for this re-dreaming, which reshapes our daily lives, as well.

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Participated in more than 500 exhibitions, amongst them in the LichtBlicke (Frankfurt am Main, German Film Museum), ELECTRA 83 (Museum of Modern Arts, Paris), Beyond the Art (Ludwig Museum), Hungarian National Gallery in the 60-ies, and so on.
His major individual exhibitions: Kunsthalle Budapest, CAVS Gallery MIT- Cambridge, Museum of Kassa, Hungarian National Gallery, etc.
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Electromagnetic Radiation from Mobile Phone and its effects on Human Brain

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Abstract

Today, cell phone technology is an integral part of everyday life and its use is not only restricted to mobile telephony but also extends to internet surfing, data and image sharing, music and video downloading etc. With increased usage and growing numbers of subscribers, concern for radiation hazards from cell phone towers have also increased. The present article deals with cell phone radiation, its interaction with cellular and sub cellular structures of the human body and resulting ill effects on human brains. Finally, a few suggestions are made to overcome the challenge.

Introduction

Discovery of telephone in March 1876 by Alexander Graham Bell was a standout event in world history for which he was subsequently awarded the first patent for electronic telephone[1]. Eversince this discovery, telephone has seen many technological changes. Worldwide, a dramatic increase of cellular phones has prompted concerns regarding potential harmful effect from electromagnetic radiation (EMR). It is well documented[2-4] that there is a close association between cell phone use and prevalence of brain tumors.

The radiation emitted by cell phones is absorbed by the brain tissue within a range that could influence neuronal activity[5-6].

In view of the proximity between radio-frequency source (i.e. mobile phones) and the human brain, several studies have investigated the effects of EMR on resting cerebral activity, but results have often been contradictory[7-8]. The EMR is characterized by its frequency, intensity of electric and magnetic fields, their direction and polarization characteristics in free space. When an electromagnetic field falls upon the human body, it partially penetrates the body and is absorbed by body tissues[9]. The adsorption of EMR is expected to raise the body temperature.

The present article discusses about the nature of electromagnetic radiation, which originate from use of mobile phones and their effects on brain tissue.

EMR from Mobile Phones Base Station

The radiation emitted by mobile phone transmission towers are electromagnetic fields in the microwave frequency range. The intensity of this field is maximum near the tower and reduces with increasing distance from the tower according to inverse law : $I \propto \frac{1}{r^2}$.

The value of electric field E_0 at a distance r, from a vertical transmitting antenna of power P, is given by Polk[10].

$$P/_{4\pi r^2} = E_0^2 \frac{\varepsilon_0 C}{2}$$

$$E_0 = \left(\frac{P}{2\pi r^2 \varepsilon_0 C}\right)^{\frac{1}{2}} = 7.746\sqrt{P/_r}$$

where 'ε_0' is permittivity of free space; and 'c' speed of light.

The electric field E_0 at a distance r, from vertical transmitting antenna of effective radiation power (ERP) of 50 w is

$$E_0 = \frac{54.76}{r}\ \frac{V}{m}$$

Thus it is clear from the above equation that electric field varies inversely proportional to the distance from the transmission tower.

Mobile phone technology and radio field

The maximum powers that GSM mobile phones are permitted to transmit by the present ICNIRP standard are 2W and 1W at 900 Hz and 1800 Hz, respectively. Generally, a part of the radiated energy will be absorbed in tissues. The power absorbed per unit mass is given by the following expression[11].

Specific Absorption $(SAR) = {(SE^2)}/_r$

where S is the electrical conductivity of tissue and r is the mass density. The SAR is measured in watts per kilogram. It varies from point to point in the body, because the electric field changes with position and the conductivity is different for different types of tissues. However, in most of the situations, SAR is directly

proportional to $1/d^r$ where d is the distance between the antenna and the head 'P' varies from 1.5 - 2.

The calculated values[3] of SAR in fat and skeletal muscle of human body from mobile phone base station are presented in Table 1 and Table 2. These tables (Table 1 and 2) clearly reveals that the harmful values of SAR for fat are up to a distance 10 cm from the base station and for skeletal muscles, these values are up to 400 cm from the base station.

Sl. No.	Distance from tower, in cm	Incident electric field (E_0) Vm^{-1}	SAR Wkg^{-1}		
			1 cm	2 cm	3 cm
1	10	547.6	10.10	3.9	2.41
2	30	163.5	0.99	0.384	0.238
3	60	91.3	0.28	0.180	0.670
4	100	54.8	0.101	0.038	0.024

Table 1. Variation of SAR inside FAT at different depths

(adopted from : Kumar and Pathak, 2011)[3]

Sl. No.	Distance from tower, in cm	Incident electric field (E_0) Vm^{-1}	SAR Wkg^{-1}		
			1 cm	2 cm	3 cm
1	10	547.6	3848.2	3674.5	3505.4
2	30	163.5	342.7	327.4	312.4
3	60	91.3	106.8	102.04	97.34
4	100	54.8	38.46	36.74	35.04
5	200	27.4	9.61	9.18	8.76
6	400	13.7	2.41	2.29	2.18
7	800	6.8	0.599	0.573	0.546
8	1000	5.47	0.383	0.365	0.348

Table 2. Variation of SAR inside skeletal muscle at different depths

(Adopted from : Kumar and Pathak, 2011)[3]

The guidelines and regulations governing the safe use of RF/microwave radiations are given by the International Commission on Non-ionizing Radiation Protection (ICNIRP,1998)[12], the Institute of Electrical and Electronic Engineers (IEEE,2001)[13], National Council on Radiation Protection and Measurement (NCRP, 1986)[14], The Australian Radiation Protection and Nuclear Safety Agency Standard (ARPANSA, 2002)[15] etc. All these agencies have set the safe limits of whole body SAR as 1.6 Wkg^{-1}.

Interaction of cell phone radiation with biological tissues

The human body (contains 70% of liquid) acts as parasitic antenna that receives the electromagnetic radiations or waves from external sources[16]. It is very similar to that of cooking in the microwave oven. The human height is much greater than the wavelength of the cell tower's transmitting signals, so there will be multiple resonances in the body, which creates localized heating inside the body. This results in the drying up of the eyes, brain, joints, heart, abdomen[17] etc . Radiation from cell phone towers has been associated with greater increase in brain tumor[18]. One of the very recent study[2] demonstrated that continuous 50 minutes cell phone exposure increase brain glucose metabolism in the region closest to the antenna. Because of electric field, E(r), produced by the cell phone, which decreases rapidly with distance from the antenna, the scientist hypothesized that the effect of cell phones on glucose metabolism would occur in regions close to the antenna and that the regions far from the antenna would show no effects. Therefore, the corrections for multiple comparisons were restricted to brain regions in which E(r) was higher than 50 % of the maximum field value E_0, in the brain ($E_0/2 < E(r) < E_0$) (Fig. 1). However, whole-brain glucose metabolism did not differ between conditions, which for the off condition corresponded to 41.2 µmol/100 g per minute and for the on condition to 41.7 µmol/100 g per minute (Figure 2).

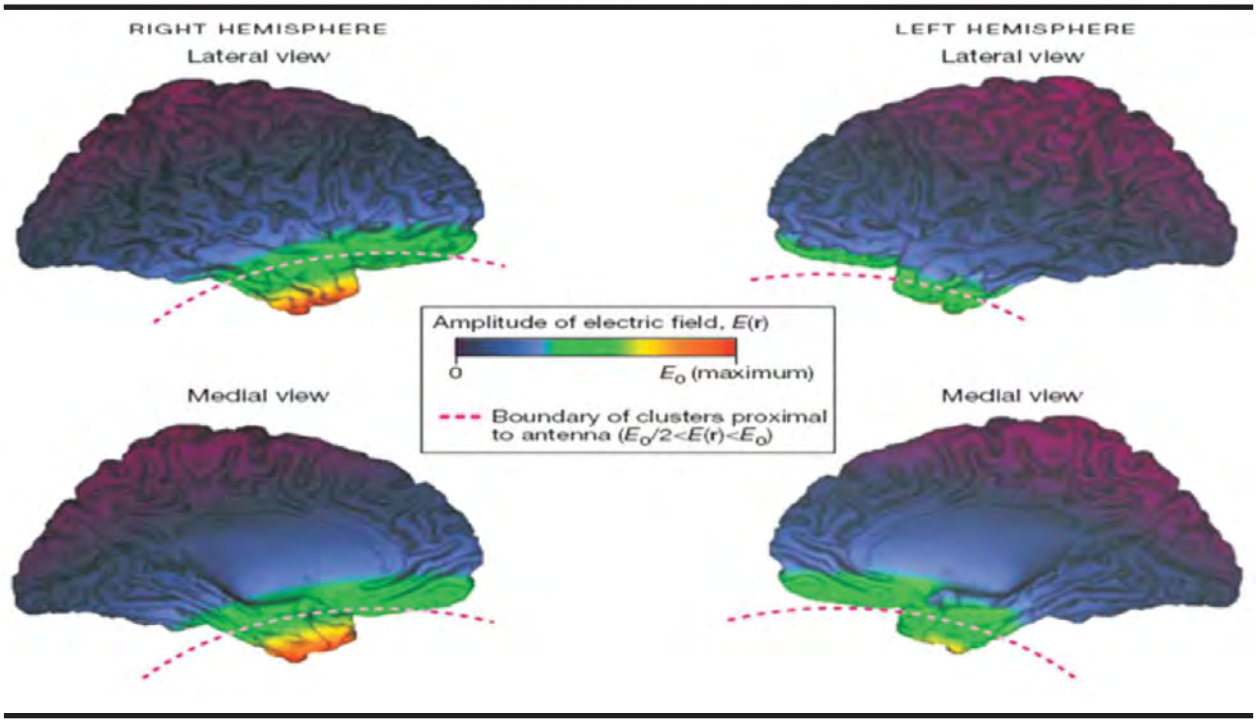
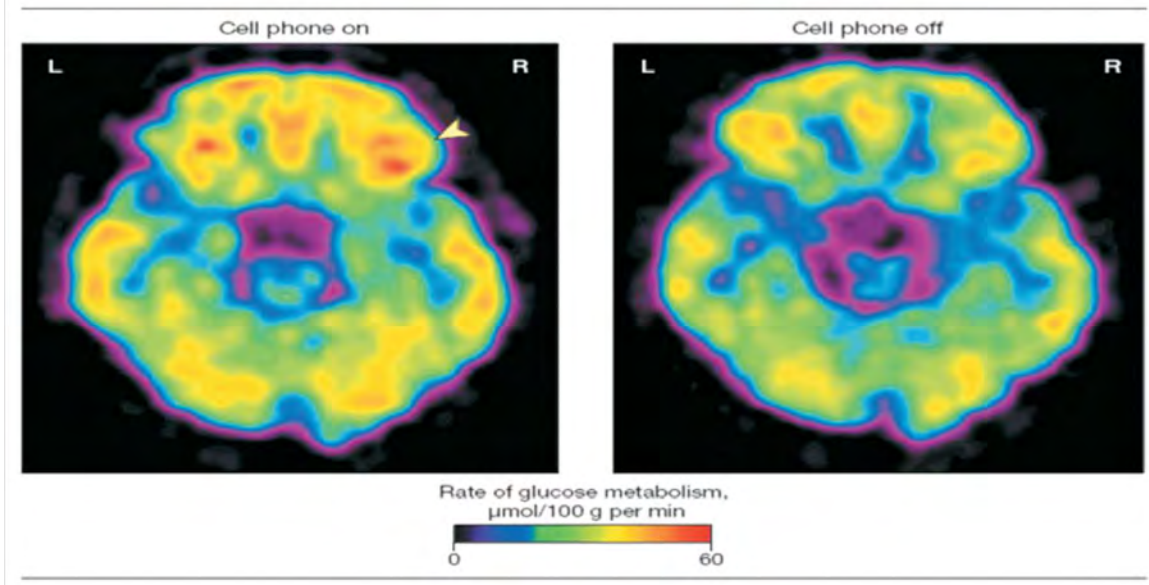


Figure 1. Amplitude of the Electric Field emitted by the right cellular telephone antenna rendered on the surface of the human brain

(Figure adapted from Volkow et al., 2011)[2]



Images are from a single participant representative of the study population. Glucose metabolism in right orbitofrontal cortex (arrowhead) was higher for the 'on' than the 'off' condition (see 'Methods' for description of condition).

Figure 2. Brain Glucose Metabolic Images showing Axial Planes at the level of the Orbitofrontal Cortex

(Figure adapted from Volkow et al., 2011)[2]

Other effects of cell phone radiation

On the other hand, Carl Blackman[19] have shown that weak electromagnetic field release calcium ions from the membranes. Moreover, leakage of calcium ions in to the cytosol acts as a metabolic stimulant, which accelerates the growth of tumors. Loss of calcium ions causes leaks in the membranes of lysosomes that causes DNA damage (Figure 3). From Fig. 3, it is also clear how cell phone radiation causes effective interaction with cellular and sub-cellular structure.

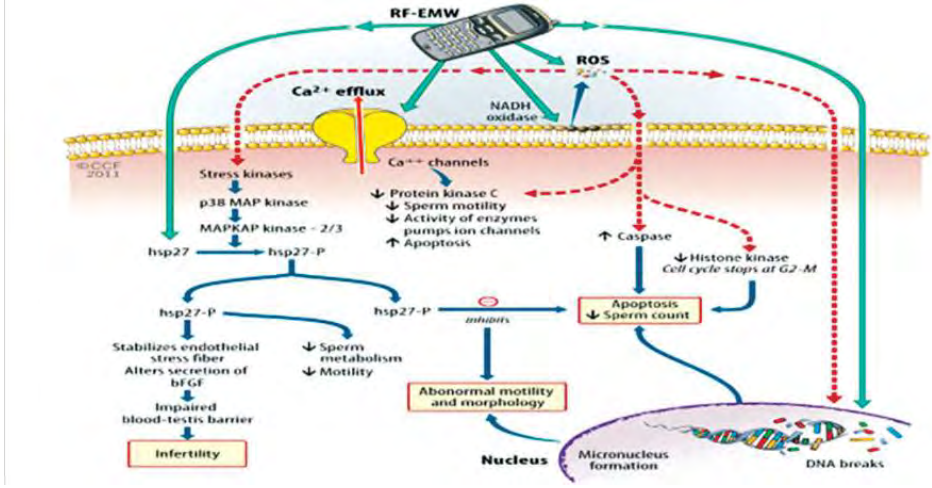


Fig. 3. Effects of RF-EMW on cellular and sub-cellular structure.

(Figure adapted from Hamada et al., 2011)[20]

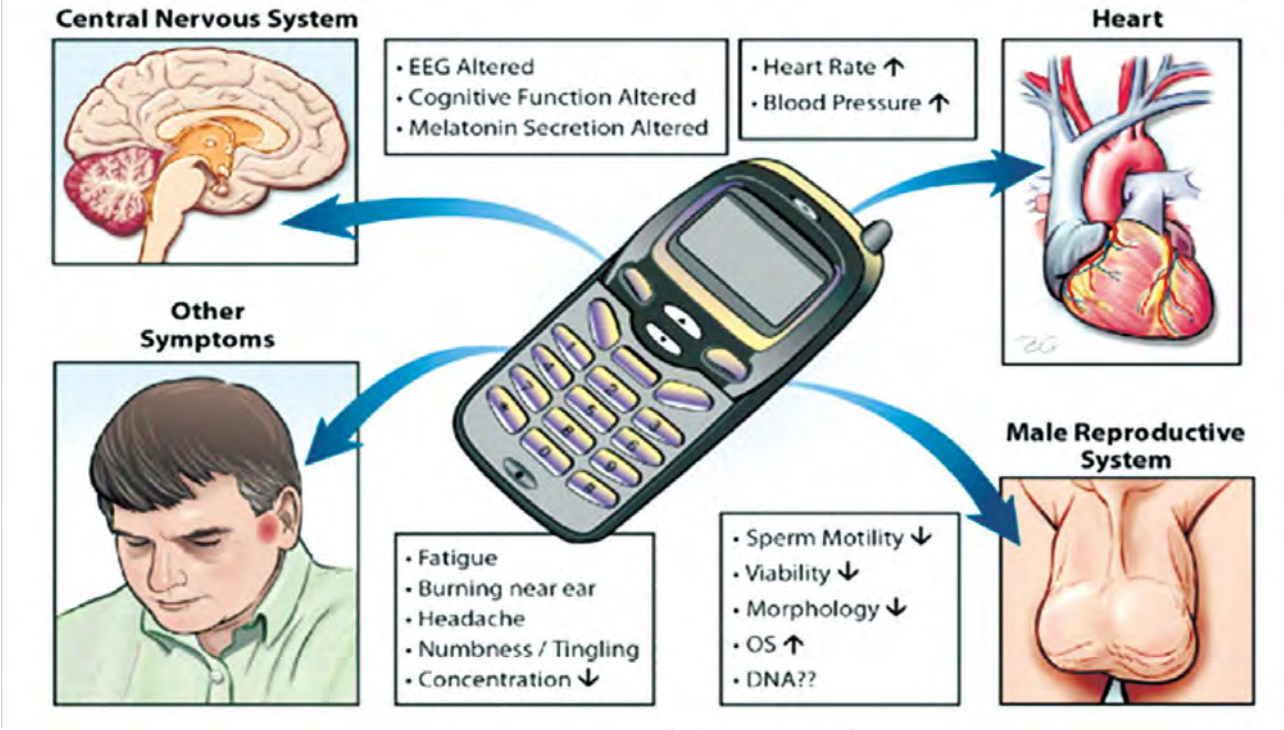


Figure 4. Gross effects of cell phone EMW radiation.

(Figure adapted from Makker, 2009)[21]

Microwave radiation damages the placental barrier, this clearly suggest that pregnant women should avoid use of cell phone[22]. A pregnant woman and the fetus both are vulnerable because of the fact that these RF radiations continuously react with the developing embryo and increasing cells. Children are more vulnerable to radio frequency (RF) radiation emissions as their skulls are thinner, their nervous system still developing and myelin sheath is yet not developed.

Moreover, RF exposure can adversely affect the heart pace maker, implantable cardiovascular defibrillators and impulse generators[23]. This RF radiation may stop peace maker from delivering pulses in regular way or may generate some kind of external controlling pulse resulting in conditions that may lead to death. Another important report from WHO[24], states that diseases like Alzheimer and Parkinson are highly connected with electromagnetic radiation. Finally at the end of May' 2011, after reviewing dozens of studies, WHO announced that cell phone may cause brain cancer and they classified cell phones as "possible carcinogenic to humans" and placed them in the same category as the pesticide DDT and gasoline engine exhaust.

Conclusions

It is clear from the study that the electromagnetic radiation discharge from different sources such as mobile phone, computer, laptop, TV towers, FM towers, microwave oven etc can be dangerous for human beings. Scientists are unanimous in concluding that excessive exposure to such radiations may lead to brain tumors. Continuous fifty minute cell phone exposure is found to be associated with increased brain glucose metabolism in the region closest to the antenna. Study also reveals that children are more vulnerable due to the electromagnetic radiation from cell phones.

Therefore, the message we want to covey towards our society is that we must be careful in our use of technology so as not to damage our own health. It is also suggested that no transmission tower should be located near populated areas and there should be strict enforcement of radiation norms from mobile phone towers. People should keep themselves at least 4 m away from mobile phone base stations and the government should take initiative to reduce the mobile phone tower radiation from 4 watt/m^2 to 0.4 watt/m^2. Moreover,

people may use headphones instead of putting the mobile phone directly on their ears.

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Beginning of Science Museums and Planetariums in India – Contribution of Ramanatha Subramanian

Jayanta Sthanapati

Introduction

Museums in India have existed in one form or other for almost two hundred years. The Indian Museum in Calcutta was opened in 1814. Other important museums of traditional nature, established during the 19th Century British India were Government Museum, Madras; Government Museum, Trivandrum; Central Museum, Nagpur; and the State Museum, Lucknow. A dedicated Museum of Industry, the Lord Reay Industrial Museum, primarily a display of collected artefacts and objects, was established in Pune in 1875. Two natural history museums were also established in British India, namely, Bombay Natural History Society Museum (1883) and Bengal Natural History Museum, Darjeeling (1903). The Indian Museum too had some collections of natural specimens. However no modern science museum fully dedicated for display of science and technology objects was established in British India.

Prof. Ramanatha Subramanian in M P Birla Planetarium in January 2013

The Japanese National Museum of Nature and Science, set up in Tokyo in 1871, was the first dedicated museum of science and natural history in Asia. India was the second Asian country to have a science museum, but only after its independence.

In early years of 1950s four Great Indians took keen interest in establishing Science Museums in the country. They were Pandit Jawaharlal Nehru, First Prime Minister of India, Shri G.D. Birla, a renowned industrialist, Prof. K.S. Krishnan, a world renowned physicist and Dr. B.C. Ray, a renowned physician and the then Chief Minister of West Bengal. With their support and under the leadership of Shri Ved Prakash Beri, Shri Ramanathan Subramanian and Shri Amalendu Bose, three science museums, namely, Birla Museum (1954) at Pilani; Science Museum of National Physical Laboratory (1956) in New Delhi and Birla Industrial & Technological Museum (1959) in Calcutta, were opened, respectively.

Prof. R. Subramanian, Director General of the M. P. Birla Planetarium, in an interview with the present author, has revealed that a few years before all those endeavours, while working as a Research Scholar at the Madras Government Museum, in 1950, he had set up a modest Science Museum cum Planetarium for the benefit of local student community. He also narrated the contribution of some great leaders of their respective fields, in establishing early science museums and planetariums in India.

Growth of Science Museums and Planetariums in India since Independence

Science Museum is used as a generic term for museums on different aspects on science and technology. It includes traditional science museum, natural history museum, science centre and science city. We now have sixty such institutions and thirty nine planetariums located in various parts of the country, engaged in enhancing public understanding of science through their exhibits and activities. [Table 1]

	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2013	Total
Science Museums	3	1	–	–	–	2	–	6
Science Centres	–	1	1	8	15	12	9	46
Science Cities	–	–	–	–	1	1	1	3
Natural History Museums	–	–	1	–	2	1	1	5
	2	2	3	7	9	7	9	39

Table 1. Science Museums and Planetariums in India since Independence

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Following is the interview of the author with Prof. Ramanatha Subramanian on January13, 2013 at the latter's office in M.P. Birla Planetarium in Kolkata.

Jayanta Sthanapati : Sir, let us begin our conversation by asking you to please give me a brief account on your origin and family background ?

Prof. Ramanatha Subramanian was interviewed by Dr. Jayanta Sthanapati

Ramanatha Subramanian : I was born on 17 February, 1927 at Dharmapuri in Tamil Nadu. My father Late Shri Ramanatha Iyer was Headmaster of a school. My mother Late Smt. Lakshmi Devi was a home maker. We are a family of orthodox Brahmins of the Sarma group. We sometimes use the title Sarma and sometimes Iyer. My parents were devout Hindus and very religious minded with weekly temple visits for pujas.

My father was a great Tamil scholar and also a great historian. He was a close friend and classmate of late Sir S. Radhakrishnan, President of India. He had exchanged letters for several decades with Sir Radhakrishnan who was Vice-Chancellor, Benaras Hindu University and when he was Spalding Professor of Eastern Religion in Oxford.

My father was very broad based in his approach to caste and was the first Headmaster of the school to admit Harijans in to school classes. In fact he had instructed me to sit in the classroom next to a Harijan student.

We were five brothers and five sisters. Both my parents were very much keen that all the children should receive the best coaching and training in education and they were following the progress in education of the children on day to day basis. They always had a great regard and respect for language, history, literature and things like that. They taught us to appreciate great people who have given their mark, in the various fields, whether music or literature or things like that.

Sthanapati : Please tell me about your school and college education.

Subramanian : I had my schooling in board high school in Krishnagiri, Hosur and Dharmapuri all in Salem District. Sometimes my father himself is to be the headmaster of that school. Sometimes, somebody else; when he was transferred to some other school. One school teacher whom I liked the most was one C.B.A. Subramanian. He frequently gave anecdotes as he was teaching mathematics on the blackboard and easily participated with the students in the jokes and stories.

I passed Intermediate Science and B.Sc. from American College, Madurai. There I essentially studied Mathematics, Physics and Chemistry with a little bout of religious instructions.

It was during the Second World War. The Principal of American College was a very broad minded neutral type of American, who used to assemble all the students and say "Whatever way you want to condemn the British you condemn, I do not mind. But you have to condemn that within this campus. Then only, I will be able to give you protection. If you go out, I will not be able to protect you. But I don't mind students trying for their country's independence and praying for it, working for it, in a positive direction. I am an American, I know my sentiments".

In 1948, I received a Master's degree in Physical Science from Presidency College, Madras. During college days broadly my aim was to become a scientist or an engineer, more towards a scientist.

Sthanapati : What did you do after completing formal education ?

Subramanian : My career plan after passing Master's degree was to become a scientist. I thought of one line, which was study of metal alloys of ancient civilization. It was called Archaeological Chemistry. A little earlier a laboratory for such study was established in British Museum in London. Harvard University also had a laboratory for studies in chemical archaeology. In India, I and one Dr. Paramasivan took first initiative to introduce the study by convincing the Tamil Nadu Govt. to set up a laboratory in the campus of Madras Museum. We started our work to examine what metals and trace elements the ancient Indians used for bronze images and things like that. We published results of our studies in the 'Current Science' journal in 1951.

Sthanapati : Did you set up a modest science museum cum planetarium in Madras Museum in the early 1950s ?

Subramanian : In 1950, while working as a research scholar in Madras Museum, with the permission of the museum authority, I installed some models on physics in a shed behind my laboratory. I also installed a second-hand table model planetarium there which I bought from a local curio shop. With all that I set up a modest science museum cum planetarium, which was occasionally visited by invited school groups.

Sthanapati : I understand you moved to the United States soon quitting assignments in the Madras Museum. How did that happen ? Where in the US you met Prof. K. S. Krisnan ?

Subramanian : Yes, I received a fellowship from the American Philosophical Society and a Fulbright travel grant to conduct research at Johns Hopkins University, Baltimore and the Smithsonian Institution, Washington D C.

While working there, once I heard that Sir K. S. Krishnan (1898-1961), the then Director of the National Physical Laboratory, New Delhi had come to Washington D. C. for giving some lecture and would visit Baltimore to see the Tulip Flower Show at Sherwood Garden. Prof. Krishnan was an associate of Prof. C. V. Raman while working at the Indian Association for the Cultivation of Science, Calcutta and had significant contribution in the discovery of Raman Effect.

I thought, I would also like to be there, and if possible meet Sir Krishnan, that will be a privilege for me. So I went. He had come with some scientists to the flower show. I met him and casually so many things were talked. Sir Krishnan had a great interest to see that India set up some science museum like the ones in London and Munich. I talked to him and told him that in India both Calcutta and Madras have already celebrated centenaries of museums of natural history and art, but there is no museum on Sciences or Engineering. He asked, "Do you have interest in that?" I replied in positive. He said, "I have been thinking that idea in Delhi. When you go back to India, after your work is over, be in touch with me. If something happens, I will call you. If you are interested you may consider the offer".

Meeting with Prof. K. S. Krishnan was a turning point in my life. That is how there was a change again, from the US laboratory I switched to Sir K. S. Krishnan in NPL.

Sthanapati : What assignment did Prof Krishnan give you in National Physical Laboratory, New Delhi ?

Subramanian : Primarily to set up a science museum. I worked in NPL from 1955 to 1961 as a Scientific Officer.

I was appointed at the NPL as a Scientific Officer for the Science Museum project. I was allotted a floor area of about 550 square meters, distributed on ground floor and a mezzanine floor for display of science exhibits.

Science Museum, National Physical Laboratory

In 1956, I started a science museum in NPL with thirty exhibits highlighting important activities of leading research laboratories in India. There were many physics exhibits, a closed circuit television set up, a varied collection of minerals, ores and crystals, a planetarium and so on.

Sthanapati : Was there any foreign consultant to guide you for the project ?

Subramanian : Dr. W. T. O'Dea, a Keeper of London Science Museum was brought to the Science Museum project at National Physical Laboratory under a UNESCO grant as per recommendation of Sir K. S. Krishnan to the Govt. of India. He worked along with me on new ideas of setting up working scientific exhibits and had also helped in getting replicas of early scientific and engineering machines and transportation models.

Sthanapati : We have heard that the science museum and planetarium at NPL became inoperative after demise of Prof Krishnan. Is that true ?

Subramanian : The museum and planetarium at NPL were having up and down situations. People were not too much interested. In fact some of them were always criticizing museum and planetarium coming up amongst priority areas of physics and chemistry and things like that. You see always science museums and planetariums had only a step motherly treatment in the Govt. from all angles. Anybody you talk either in the Secretariat or within the scientists. This is not a priority area.

Prof. Krishnan passed away in 1961 at the age of 62. He was quite active at that time. Suddenly one night he died. You see, he had a great soft corner for the sub-staff. If they made any complaint to him, it will never go unheeded. One day, it was a hot day, it was June, some of the sub-staff complained to him that no administrator, no scientists are going towards their quarters and looking after their interests and all that. One Mustafi was the Administrator. He was an IAS man. Later, I am told he became a Secretary of the CSIR. So he called Mustafi and said, "What is it there ?" "Sir they will complain many thing. I will take you one of the days". "No, no, no. I want to go now". "Sir, it's a hot sun, where are you going ?" "No, no, give me an umbrella. I will go with you". They walked that distance all the way to the quarters. When he came back he was very tired due to heat of the sun. That night he passed away. So, the science museum and planetarium lost their importance in the NPL.

Sthanapati : What compelled you to move from NPL Museum, New Delhi to Birla Planetarium, Calcutta ?

Subramanian : In 1961, the big planetarium here (in Calcutta) was coming up. It was a dream project of Shriyukt Madhav Prasad Birla. Then I was wondering, Sir Krishnan my mentor, my Guru, my God has passed away. I thought what I should do? I was still in the Govt. So, I was thinking about the planetarium. I went to CSIR to ask them, whether they will release me on lean for two years to go to Calcutta, which has been a seat of many activities, always taking a first place, whether it is a museum or University. Both Chennai and Calcutta used to be competing in each and everything.

There was one Deputy Secretary in CSIR, I think his name was Agarwal. He asked me "What is the matter"? I said "I have come from NPL, I have substantive post there. But this (planetarium in Calcutta) is coming up, can you possibly give me lean for two years to go there"? "You are in a Govt. body here, sponsored Govt. body. You want to go to another institution there, how is it possible ? It is not possible". I came back to NPL.

Next day morning the same Agarwal telephoned NPL to connect me. I was on the line. "Yesterday you came to me for going to Calcutta". "Yes, but you said it is not possible. So I dropped the idea and dropped it from my mind also". "No, no, no, don't do that".

Mr. M. P. Birla and Prof. Humayun Kabir, a Cabinet Minister at that time, were close friends. So he told Kabir, "I am setting up this big planetarium. I don't see anybody in this country. There is one man who is working at NPL, why don't you spare him"? So Prof. Kabir wrote a note to Prof. M. S. Thaker, DG CSIR at that time. "What is delaying Subramanian's departure ?" This was the note. He did not say for what and where and when. The moment the note came, they tried to find out who is this Subramanian. What is he doing ? Finally, the Secretariat people located me and this man said, "You come, I want to talk to you". "What is the use of coming?" "No, no, you come to me". When I went,

he said, "Whatever conditions you want for the lean you jot down and give me. I will get it signed by the minister. Immediately you go to Calcutta". That is how I came here for two years on lean.

Sthanapati : Sir, you had worked with Syt. M. P. Birla for many years, tell us something about his industrial ventures and philanthropic activities.

Subramanian : Syt. Madhav Prasad Birla (1918-1990) was born in Bombay. He was universally and affectionately called Shri M. P. Babu. His uncle, the legendary Syt. G. D. Birla inducted him into business at the early age of eighteen. As was the practice in the Birla family, he was given a small fledgling company known as Birla Jute & Manufacturing Company Ltd., which he built by sheer dint of dedicated hard work and enterprise, into a multi-product industrial giant encompassing products like jute, cement, calcium carbide, synthetic yarn and others. A man of great enterprise, Shri M. P. Babu set up a host of other companies like Universal Cables, Vindhya Telelinks, Hindustan Gum & Chemicals, Digvijay Woollen Mills, Indian Smelting etc., all leaders in their own fields, manufacturing quality products. His contribution to the banking sector was equally significant as Chairman of the United Commercial Bank till its nationalization.

Syt. Madhav Prasad Birla

Shri M. P. Babu will also be remembered as a great philanthropist. Totally devoid of ego, and instinctively averse to self-advertisement, he gave profusely and generously to charitable causes spread over the length and breadth of country. He gave to it the Birla Planetarium, Kolkata one of the finest in Asia and the Belle Vue Clinic & Nursing Home, Kolkata one of the best equipped medical institutions in this part of the country. He established the M. P. Birla Foundation in fulfilment of his deep commitment to furthering progress in the fields of education and medicine. The Foundation has also set up and operates a modern 60-bedded hospital at Birlapur in West Bengal, with a second hospital operating, at Satna in Madhya Pradesh. Shri M. P. Birla was also intimately associated with the famous Birla Institute of Technology and Science at Pilani.

Sthanapati : Was the planetarium in Calcutta, conceptualized by Syt. M. P. Birla ?

Subramanian : Syt. Madhav Prasad Birla, during 1950s, had been seeing, visiting various planetariums in Europe and America. So he wanted to set up a planetarium in Calcutta.

Sthanapati : Birla Planetarium was a non-governmental project. What support did Syt. Birla get from the local or central government ?

Subramanian : Dr. Bidhan Chandra Roy (1882-1962), the then Chief Minister of West Bengal was very keen to have a planetarium in Calcutta. Earlier due to his initiative Syt. G. D. Birla had donated his residential building to Govt. of India to set up Birla Industrial and technological Museum in Calcutta. So, when requested by Syt. M. P. Birla, he arranged to allocate this vantage plot of land of two acres, where we are now, in Calcutta maidan for the planetarium.

Dr. Roy used to visit the planetarium in the making, but was not present when it became operational on 29th September 1962. He had expired earlier on 1st July in the same year. I remember, M. P. Birla was almost in tears when he heard that Dr. B. C. Roy had passed away.

Sthanapati : Was there any building, trees, road, etc. on the land allotted for the planetarium ?

Subramanian : Two old big trees were there. The trees were felled. As the felling was taking place, there was lot of up roar in the press – 'Vanishing Maidan'. There was a lot of protest from the public. But finally when it came, people realized a new type of institution for this country is coming for the first time here and in a very big way. So, they forgot about the trees.

Sthanapati : Who were the architects and constructors of the planetarium building ?

Subramanian : M/s Ballardie, Thompson & Mathews were the architects and Mr. J. K. Gora was the chief architect and he was another man very meticulous in work. He will ask M. P., Sir you come with me and see what I have done and tell me where you want me to change ?

Architecture of the planetarium building was based on Sanchi Stupa. Somebody was asking, why a Buddhist Monument was chosen? I would not be able to answer this, because never have I probed M. P. Birla, either directly or indirectly to find out why he chose that? But one thing is clear, that Sanchi Stupa has a nice dome, a big dome, so that fitted well.

M/s M. L. Dalmiya & Co. Ltd. had constructed the planetarium building. With its huge hemispherical dome, measuring 23.2 meters of inner diameter, it was the largest in Asia at that time.

Sthanapati : When was Birla Planetarium inaugurated ?

Subramanian : It was formally inaugurated by Pandit Jawaharlal Nehru, Prime Minister of India on 2nd July 1963. Birla Planetarium was later renamed as M. P. Birla Planetarium.

Sthanapati : It seems our Prime Minster, Pt. Jawaharla Nehru had interest in all initiatives to establish science museums and planetariums in India at that time.

Subramanian : Pandit Nehru had significant contribution in establishment of Birla Museum (1954) at Pilani, Science Museum at NPL (1956) in New Delhi, Birla Industrial and Technological Museum (1959), Calcutta and Birla Planetarium (1963), Calcutta.

Sthanapati : The Planetarium instrument has been surviving for more than 50 years. Could you elaborate ?

Birla Planetarium was inaugurated by Pandit Jawaharlal Nehru on 2nd July 1963

Birla Planetarium in late 1960s

Subramanian : The main instrument is the universal planetarium instrument, which is available for any latitude in the northern or southern hemisphere. It can be set for any date, past or future and the planets are all linked up with that. When I say planets are linked up, that itself is a sort of precise analog system so to say.

The instrument was manufactured by Carl Zeiss at Jena in East Germany. As you might have known, Carl Zeiss Germany at Jena split into two parts after the Second World War. Some of the engineers and scientists moved over to the West Germany, to a place called Oberkochen, and set up another Zeiss factory called Carl Zeiss AG. Now both of them enjoy equal status.

But our equipment was from East Germany, because we had some rupee trade agreement with some of the countries. We imported it in 1960.

This type of instrument has a lot of testimonials so to say, and we have been running that from the very beginning, since 29th September 1962. All this years, it has been running, it is also a proof of the quality and the engineering accuracy of the Zeiss machines.

Carl Zeiss Planetarium project is operational in M P Birla Planetarium since 1962

Sthanapati : With how many staff the planetarium started functioning?

Subramanian : The planetarium started functioning with 3 Lecturers, 1 Instrument Engineer, 1 Assistant Engineer and 2 staff members to handle complete AC plant, a host of mechanics, 4 Ushers, 3 Darwans and 2 Gardeners. The planetarium had the necessary administrative and accounts staff apart from the ticket sales staff.

Sthanapati : To whom would you give maximum credit for keeping the planetarium projector functional for such a long time ?

Subramanian : Our Engineer Mr. D. K. Roy, had been sent and trained in Jena Works itself for six months, after he was employed by us. He was in England when he was employed. So he was asked to proceed to Jena and be under training and then come here. Afterwards, he had taken full charge here. He was very meticulous in his work, very careful in observations. He had also maintained link with Carl Zeiss and interacted with them periodically, whenever they came here or happen to be in India.

We never had the necessity to close down the planetarium, even for a day because of some problems with the instrument. Occasionally, because of Holi we might have closed, not otherwise. Every show was done. Even if some problems were there, even through a show, quickly we will manage it, continue the show and finish it. Whatever was needed later on we tried to improvise it from local markets with an equivalent product, which may not be always Zeiss product, but which will serve our purpose.

He felt the instrument and the planetarium his responsibility, to see that everything goes on well. In 1969 or so there was a big crowd in the maidan, where the police employed lathi-charge and things like that and thousands of people rushed towards the planetarium, they were breaking the glasses and all that. Seeing the crowd coming rushing, I called Roy, told him "Shut up all the machines, and send out the people, close the planetarium, I will also escape with the crowd, you also escape to your quarters". Roy went to the central part of the auditorium and stood at the centre where the instrument is there, from the platform with folded hands, "You damage all the planetarium, I will not report anything bad about you to my management. But, please, please don't put your hand on the instrument. If the instrument cracks, Calcutta will lose this unique instrument; which has been set up by the first planetarium". The crowd although so big, understood the meaning of that statement and did not harm the planetarium instrument.

Many a time D. K. Roy would say, "Sir when you retire, at that time I will also retire". But he passed away due to some cerebral problem. Ever since he passed away, still I am without one limb, as it were. That is how my mental makeup is, because he had a type of dedication which was unique.

Sthanapati : Do you think dedication is still there or people think this is a kind of job ?

Subramanian : Birla Planetarium has flourished due to dedicated work of its associates. You see, some dedication is there and that number or percentage is coming down. At my times, a professor had a Govt. quarters, four bed room quarters. He was happy. He would continue, continue as a professor. People were bothered about their books, their publication, what response it had, what recognition it had, and so on.

Today our approach of life and living standard has changed. Now it is a question of job, money, facilities, comfort. Some scientists now a day are competing with business people in the facilities they are enjoying. The business man has wall to wall carpet in his house. Why I could not have? Of course there are exceptions. The whole world is going through a change. We cannot blame that also.

Present view of M. P. Birla Planetarium in Kolkata

Sthanapati : Did you ever set up an Astronomical Observatory in the planetarium ?

Subramanian : Till now we are not having an observatory as such. Some 20 years ago, I had moved for procurement of Celetron C14 telescope, which is manufactured in USA. I wrote several times to them, on some excuse or the other, they were not giving me the quotation. Then I wrote to some German firm, who immediately responded. That is how I imported it, though American equipment from Germany. It has got several attachments. Filters are there. It is also computerized. You can set the coordinates and it will chase it. It was set up on the terrace of the M. P. Birla High School in Kolkata, where we had used a sliding roof type of observatory. Mr. Piyush Pandey, Assistant Director, at that time had taken a lot of interest in that type of thing.

Sthanapati : Kindly tell us briefly on the Planetarium's Graduate Diploma Course and Research activities in Astronomy and Astrophysics.

Subramanian : We had introduced the Post Graduate Diploma Course in Astronomy in 1998. It was possible due to sincere cooperation of two eminent personalities of Kolkata, Prof Mrinal K. Dasgupta, former Director of Institute of Radio Physics and Electronics, and Prof. Amalendu Bandyopadhyay, former Director of Positional Astronomy Centre. I had developed course materials in collaboration with them, which we are still continuing with some modifications on the topics. We award the diploma. It is not linked up with any university. About twelve years ago, we recruited Dr. D. P. Duari, who had earlier worked with Dr. Jayant V. Narlikar in IUCAA (Inter-University Centre for Astronomy and Astrophysics), Pune. As Director of Research, Dr. Duari has been conducting research in Astrophysics from our planetarium.

Sthanapati : How did Dr. Ramatosh Sarkar, a mathematician, help the planetarium in reaching its goals ?

Subramanian : Dr. Ramatosh Sarkar worked with us in Birla Planetarium as a Curator for more than 30 years. He was a very cooperative, very congenial, very knowledgeable person. Sarkar was with me almost from the beginning. At that time he was an M.Sc. in mathematics. We took him initially as a lecturer. He worked under me – in the sense it's not as a higher staff to a lower staff, very close. If he has a problem he will come to me. Even if M. P. Birla created the problem, before answering him, he will come to me. As a matter of fact once he wanted to go to Japan for a conference. He was short of money. He approached the Birla Group for some extra money. It was not forthcoming. He asked me, "They have said no. Shall I still try other sources and if I manage to get that balance of the amount shall I go?" "Yes you may go, but perhaps you may antagonize the big bosses. This is my suggestion only. But if you are convinced, proceed." What I am saying is in all matters like this he would consult. Hierarchy of his discipline, everything was a much sacred to him as it was to me. I myself has been brought

up and grown where hierarchy matters a lot. But now-a-days it is going off in various places, which is a part of the change that is happening.

Sthanapati : I believe, Dr. B. G. Sidharth, founder Director of B. M. Birla Planetarium, Hyderbad had also worked with Birla Planetarium for many years.

Subramanian : Burra Gautam Sidharth was one of the few very bright students of our evening course on Popular Astronomy. He was with Birla Planetarium for about 15 years giving lectures. It was in 1966 or so. One day I asked Sidharth, "If I give you some part time lecturing work, would you be able to take it"? "I don't think Sir, I don't think so". He went away. He was a student in the Intermediate of St. Xavier's College.

After two days, Sidharth came to me. "Sir, I have thought about the whole thing again, I will try Sir". 'OK, I am glad you are prepared to take". That's how I brought him, tried him and even when he was a student I gave him some part time lecturing work, which he was doing well. He also moved up, M. Sc. and all that. Then he was getting employment in St. Xavier's College. Then I said, "Would you take a job as a part time lecturer"? "Yes", he said. I made him a part time lecturer. After sometimes I asked him whether he will become a full time lecturer here and a part time lecturer in St. Xaviers College. He agreed. Here he was working for his doctorate. That also I encouraged him to work. Sidharth moved to great heights, probably he is in a position, bigger and higher than me. I am very happy for that.

Sthanapati : When was Birla Institute of Fundamental Research formed and how is it linked to M. P. Birla Planetarium ?

Subramanian : The Birla Planetarium or M. P. Birla Planetarium was first set up by the Birla Education Trust, Pilani. Later it was shifted to the unit called Birla Institute of Fundamental Research, which was a new trust, set up about 30 years back under M. P. Birla Group. So, Birla Institute of Fundamental Research is the parent body of the planetarium.

Prof. R. Subramanian not only adorned the position of the chief executive of M P Birla Planetarium over 50 years, his dedication and vision took the Planetarium to an institution of national and international importance. His association during these years have directly or indirectly benefitted many science museum and planetarium projects in this country. He was elected a Fellow of the Royal Astronomical Society, London in 1963. He was elected Vice-President of the International Planetarium Directors' Congress in Moscow in 1987. Prof Subramanian became the President of the International Planetarium Directors' Congress in 1999 in Florida, a position he held until 2004.

Dr. Jayanta Sthanapati is a PhD in Physics from the University of Calcutta and a PhD in History from Jadavpur University. As a science museum professional he held positions like Director, Birla Industrial and Technological Museum; Director, National Council of Science Museums (Headquarters) and Deputy Director General, National Council of Science Museums. He is currently a Project Investigator to study the 'History of Science Museums and Planetariums in India', a research project sponsored by the Indian National Commission for History of Science of the Indian National Science Academy.
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Planetarium at Calicut - Malabar's Astronomy Hub

V. S. Ramachandran, Jayant Gangopadhyay

Abstract

The Regional Science Centre & Planetarium at Calicut, popularly known as the Calicut Planetarium, is the preferred destination of astronomy enthusiasts in and around Malabar. Come any news about a celestial phenomenon, the telephone of this institution starts ringing. For the local public, students, and the press and media people, this institution is the only reliable source of information on astronomical events.

This paper discusses the astronomical heritage of this renowned institution and its technical evolution over time. It focuses on the recent struggle of the planetarium to remain technically up to date and how it succeeded in doing so.

Introduction

Figure 1. Oskar Won Miller

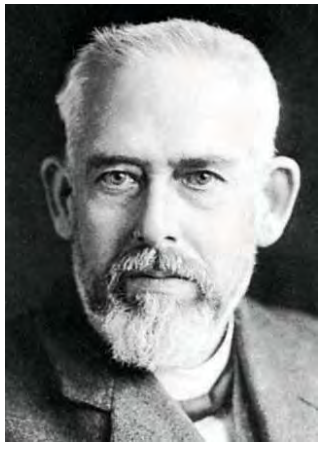


Figure 2. Max Wolf

The Year 1903, Oskar Won Miller, polymath engineer interested in all aspects of science and technology founded the Deutsches Museum. In 1913 astronomer Max Wolf had suggested to von Miller the idea of a device for his museum which would reproduce not only the stars but also the planetary motions. Von Miller approached the well-known optical firm of Carl Zeiss in Jena, who in turn agreed to look into the problem.

Around March 1919, Walther Bauersfeld, chief design engineer and later director of Carl Zeiss, hit upon the idea of projection of the celestial objects in a dark room. On October 21, 1923, Prof. Bauersfeld demonstrated the projector to a congress at the museum, the first official public showing. The professional and public reaction was enthusiastic.

Figure 3. Walter Bauersfeld

Today the planetarium, both as a fine instrument and as an institution, has come a long way since 1923 when astronomer Elis Stromgren wrote : *"Never before was an instrument created which is so instructive as this; never before one so bewitching; and never before did an instrument speak so directly to the beholder. The machine itself is precious and aristocratic... The planetarium is school, theater, and cinema in one classroom under the eternal dome of the sky."*

Cutting across the matrix of geography it took almost three quarters of a century for the distribution trajectory of this coveted device to be drawn over Calicut, a small city of distinct heritage in Kerala; the god's own country. On 30th January 1997, RSC & Planetarium, Calicut, the first planetarium in the Malabar region (northern part of Kerala) opened its doors to the public housing a 250 seater planetarium with RFP DP2 Space flight projector from Carl Zeiss.

Technical Flashback : *An idea – A plan*

Today, the planetarium at Calicut is one of the most successful planetariums of India. But its historical development was not so smooth. It went through turmoil and setbacks. We will briefly discuss the historical background of this institution.

The planetarium was inaugurated in 1997 but its history begins almost a decade and a half before, in 1984. Mr. K. C. Shankaranarayanan IAS and the then chairman of the Calicut Development Authority (CDA), was the

Figure 4. RSC & Planetarium, Calicut

Figure 5. Construction works of Science Centre, Calicut

visionary behind the formation of the planetarium at Calicut.

The Calicut Planetarium Society was formed and registered under the Society Act on the first day of August 1984 and Mr. Sankaranarayanan was one of its members. On 20th May 1985 the former Kerala Governor Shri P. Ramachandran laid the foundation for the Calicut planetarium on the 5.6 acres of land donated by Calicut Development Authority at Jaffer khan Colony. But the Society could not manage the financial requirements to nurture the project. On approaching the state government for assistance, it was handed over to the Calicut Development Authority (CDA) in 1987. The main building of planetarium was then constructed based on a design by architect N. M. Saleem. But the planetarium could not be made functional.

NCSM's Entry

Government of Kerala then invited National Council of Science Museums (NCSM) to take over the project from CDA. NCSM on its part proposed to develop a science park and a science centre in the same compound where the planetarium building was erected.

By 1987, NCSM completed the construction of science centre and the remaining works of planetarium. Further NCSM had a range of negotiations with M/s Carl Zeiss and CDA towards planetarium equipment installation. It was found that due to poor storage of the projector instruments and accessories, the electronic circuits were partially damaged and the computers were fully non functional.

In April-May 1994, the planetarium equipment was installed. During installation Zeiss engineers observed that the master computer had become dormant and so they installed the equipment in manual mode through the slave computer. Thereafter the equipment was on trial run for about a month.

The cloud of uncertainty was still around as the slave computer too had started malfunctioning. Talks were again held with Zeiss for a possible solution. But it was not possible to arrive at a compatible rate for the recovery tasks. Making projection system fully functional required total refurbishing of the equipment involving exponentially high cost compared to the budget estimate.

With the failed master computer and the slave computer malfunctioning, chances were remote that the planetarium projector could be made to work on the auto function mode. Further, frequent breakdowns of electronics were a great hindrance towards inaugurating the planetarium for public show.

At this juncture, NCSM decided to take up the work domestically. By the last quarter of 1996, a technical team of NCSM started work at site for fixing the problem. The team thoroughly studied the electronics system of the equipment and made the projection system fully functional in manual mode using relay based switching thereby avoiding the microcontroller circuits and original power supplies.

On January 30th, 1997 the then chief minister of Kerala

Figure 6. Calicut Planetarium inauguration

Mr. E. K. Nayanar dedicated RSC & Planetarium to the people of Kerala marking the golden jubilee of International Council of Museums (ICOM). The Planetarium has since then become the major crowd puller for this centre.

Trouble Shooting of the Machine

Though there were some teething problems, the planetarium gradually picked up steadfast growth. But problem erupted out of the blue. Due to unknown reasons, some insulation layers from the horizontal slip-ring of the central projector burned crippling all the main motions (the diurnal, polar and annular motions). Replacing these burnt slip-rings was an uphill task involving complete dismantling of the projector.

A major repair of the machine was now inevitable. During June 1999, the technical team of RSC & Planetarium Calicut undertook the challenging task of dismantling the system and carrying out the repairs needed. The task went through the whole gamut of overhauling work to bring back all required functions to life. Success was smelt at every stage. Though the functions were retrieved, the absence of automation still remained a handicap. However, the time was ripe for getting the equipment automated.

Automation – Initial Trials

First, few energetic young engineers from National Institute of Technology, Calicut offered to undertake the automation works of this planetarium as a part of their project works under Dr. P. C. Subramaniam,

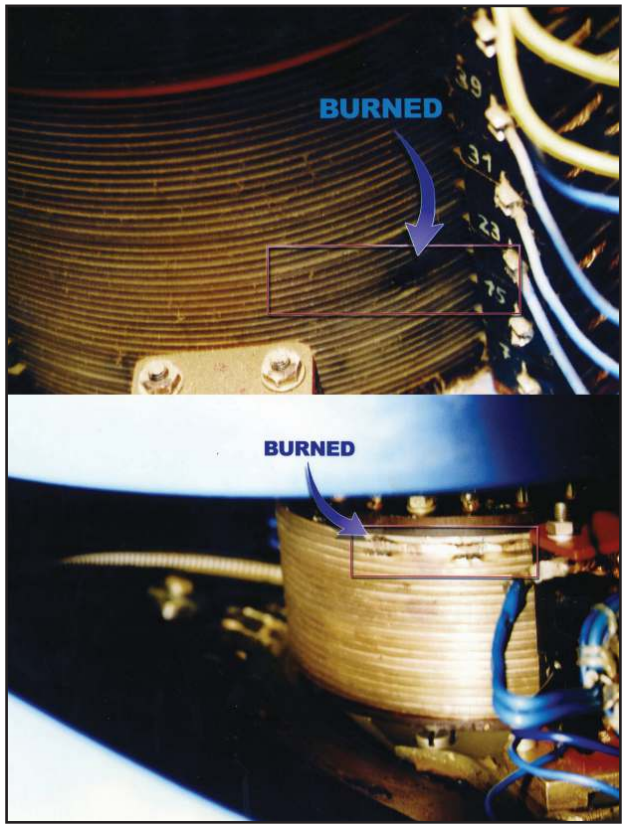


Figure 7. Slip ring Burning

Professor of Electronics & Communication Engineering Department. They developed the prototype circuits. But it was found not meeting the industry standard for further investment on these prototypes.

During 2007, the Centre of Electronic Design & Technology of India (CEDTI), Calicut offered to undertake the automation work in phased manner. In the first phase they proposed to work on the motion control. The job was assigned to them and in the first phase, the four main motions of the opto-mechanical projector were restored.

Subsequently in phase 2, which was undertaken during 2009, CEDTI restored the dimmer circuits for lamp control and automated it using Graphical User Interface (GUI) and Microcontroller technologies. The unit consisted of three modules, namely the Power Module, Control Module & Driver Module.

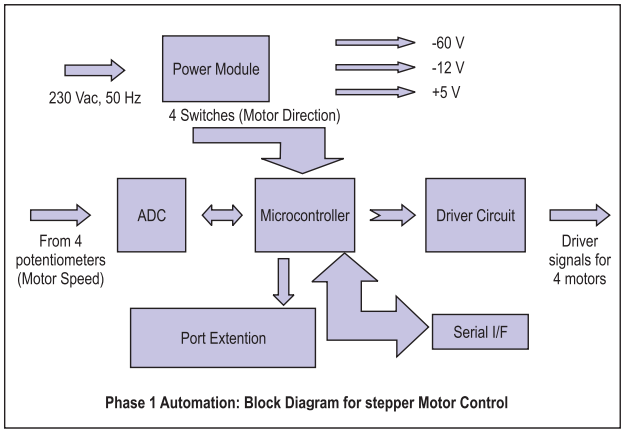


Figure 8. Phase 1: Layout

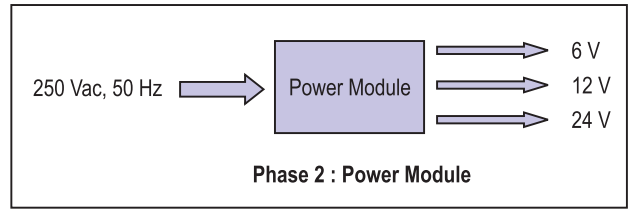
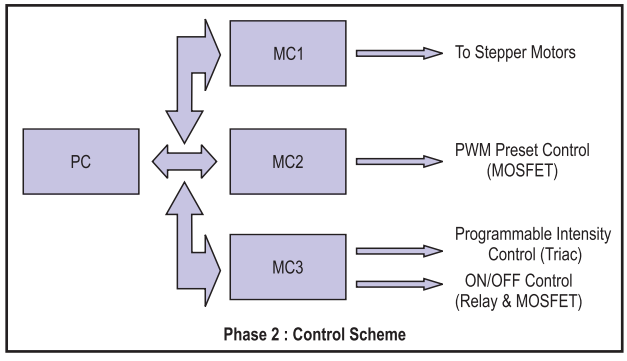


Figure 9. Phase 2: Power Supply



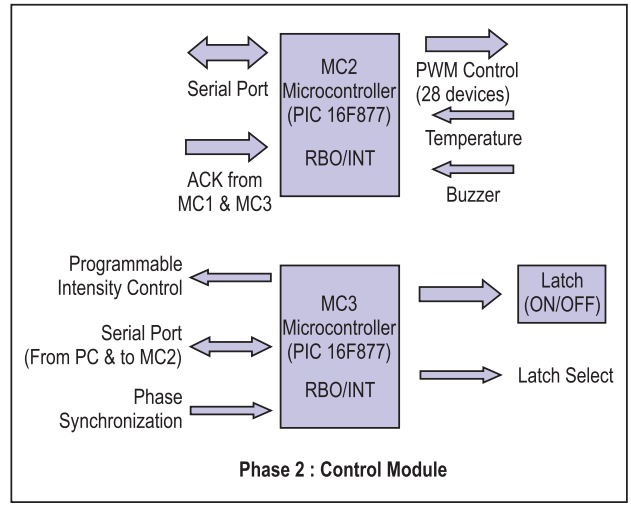


Figure 10. Phase 2 : Control Scheme& Control Module

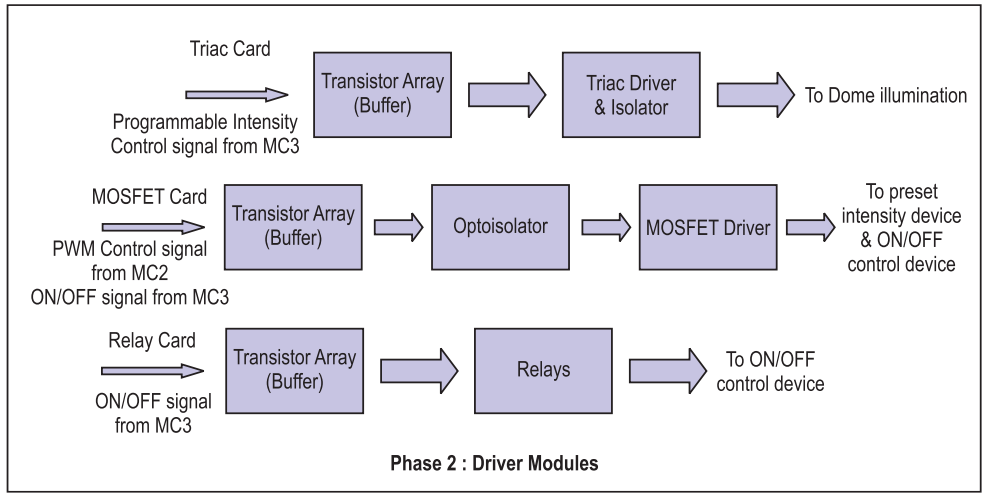


Figure 11. Phase 2 : Driver Module

The Power Module meets the power requirement of the entire unit. The Control Module, which forms the heart of the system, consisted of three micro controllers, namely MC1 (Amtel 89C52), MC2 (PIC 16F877), MC3 (PIC 16F877).

Microcontroller MC1 controlled the speed and direction of the stepper motors. MC2 was used to control the preset control devices with fixed soft start and soft decay. MC3 was dedicated for controlling the programmable intensity devices, and ON/OFF control of remaining devices. Preset controls were implemented through MOSFETs. ON/OFF controls were implemented through relays and MOSFETs.

The planetarium show was configured through the GUI on PC. On running a particular show, the PC transmitted commands to the microcontroller based hardware unit on real-time basis. Data transmitted by PC were received by all the microcontrollers, and the controllers responded depending on the address code assigned to them.

Controllers were associated with Driver modules to meet the drive requirement of the devices controlled by them.

The team from CEDTI did a good job and the system could be automated at last. But the GUI was not powerful as per requirements of a modern planetarium. It still was quite an achievement and a first step towards automation.

Modern planetarium software has the capabilities to integrate the advantages of the opto-mechanical and the digital full dome projection system. Our planetarium lacked the digital full dome projection system. Further, the power of the modern planetarium software lies in the in-built library functions, which facilitates creation of virtual projectors for spot projection in any part of the dome, animate text and graphics and the throw area covers the total dome area. Thus, though we have made some improvement through the works of CEDTI, ours was no way comparable to a modern planetarium.

Major Technical Up-gradation

Finally, NCSM wanted the planetarium to be upgraded with the latest technology from reputed planetarium equipment developers and transform the equipment to a hybrid one. This was done through a global tendering process. The jobs were to fully refurbish and upgrade the equipment and also to provide a full dome shadow-free digital projection solution to the existing system. M/s Carl Zeiss emerged as the successful bidder in the process.

Carl Zeiss in fact undertook a technical challenge. They were supposed to work on a fully altered old system, which had in course of time become a testing ground for trials and experimentation towards finding alternative economic technical solutions. This equipment had to be restored and upgraded to attain the capability of an advanced planetarium system.

The job involved repairing of mechanical parts, optics, electricals, electronics, calibrations etc. New control system had to be designed, slip rings had to be replaced. Dimmer and soft start had to be redesigned and switches had to be changed. A modern interface was to be designed, which could be integrated with the Zeiss Planetarium Software Powerdome® system. This was necessary to integrate this opto-mechanical system with the full dome digital solution. Further, because Zeiss had stopped making this particular model of the opto-mechanical machine, the task became all the more challenging.

Carl Zeiss engineers Mr. Sven Huthuff, Mr. Dima Aljechin, Mr. Andre Frenzel along with an Indian Technical Team faced the challenge successfully. While Mr. Sven worked on the electronics in the opto-mechanical side, Mr. Dima put tremendous efforts in calibrations as well as in optics and Mr. Andre was the man for looking after the digital projection system. Indian team supported them enthusiastically.

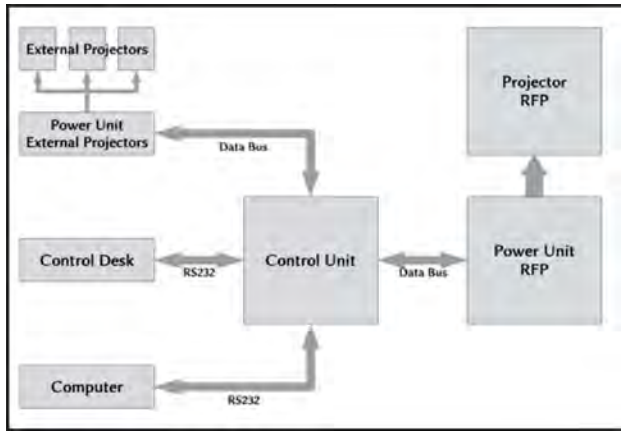


Figure 12. Plan of the Upgraded System

For a full dome digital projection system, the already commissioned large size RFP DP2 at the centre of the planetarium put hindrance towards creating a shadow free projection on the dome. The number of digital projectors required for the same had to be optimized, which could cover the full dome so that no shadow of the central equipment fell on the dome at any orientation. This required the use of simulation technologies. Zeiss engineers simulated the dome of the Calicut Planetarium on their computer system, using their own simulation software, so that depending on the light cone, the number of projectors could be optimized. On doing so, the optimum number turned out to be nine.

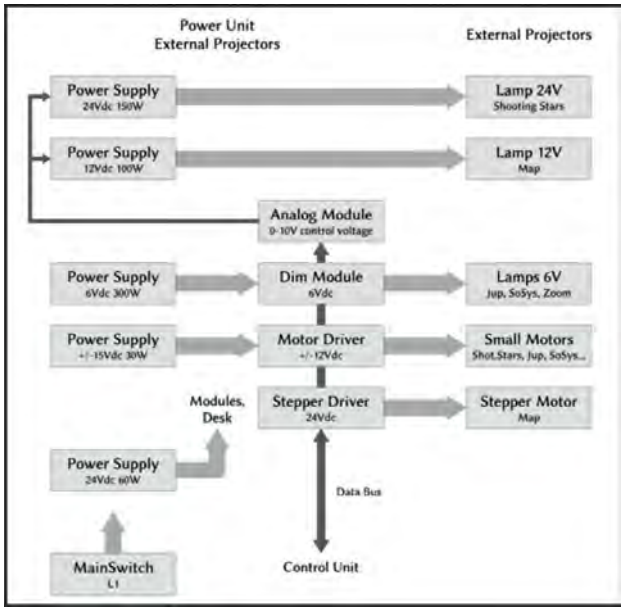


Figure 13. Power Unit Layout for External Connection

Carl Zeiss used nine channel full dome projection system, consisting of nine number of JVC DLA RS60 projectors having resolution of 1920 X 1020 and brightness 1200 ANSI lumen, with customized lens shutters for image blending and black level; nine channel image generator with Powerdome® software, NAS Data server (Network Attached Storage). This unit consisted of PC cluster with software for image generation, distortion correction and blending, Powerdome® configuration, editor, player, PDA (*Personal Digital Assistant*), libraries etc.

Also, Uniview® was installed in the Planetarium machine. Uniview® is 3D astronomy software. Uniview couldrun on ZEISS Powerdome® as special

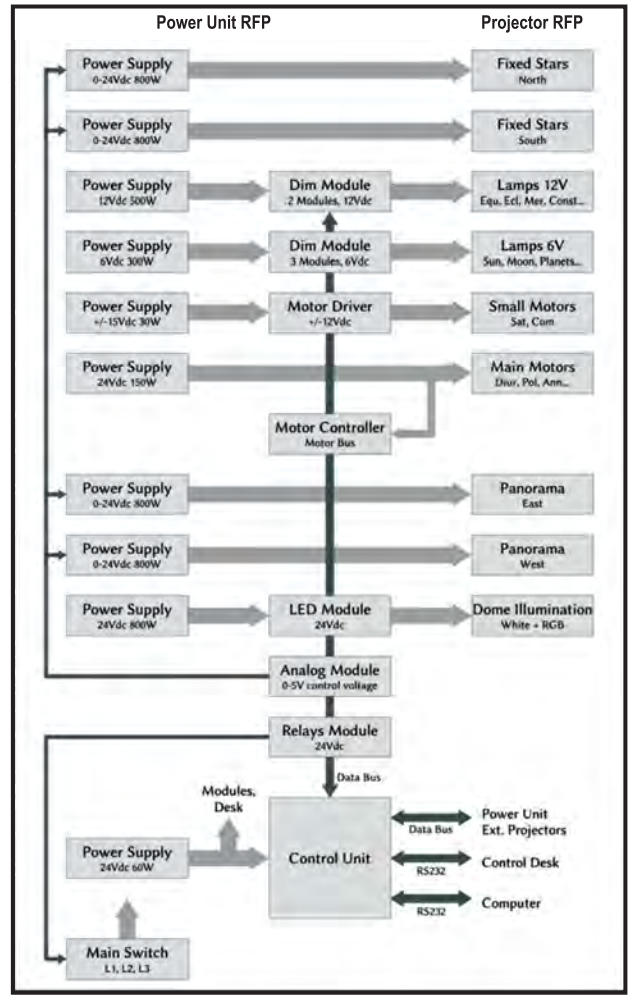


Figure 14. Power Unit Layout for Refurbished RFP DP2

adaptation was incorporated for multi-channel blending of Powerdome®. As Uniview® is separate real-time software, it was possible to run Uniview independent of Powerdome® for full-dome displays. Since Uniview would only get access to the graphics boards if Powerdome is switched off, Carl Zeiss programmed a special interface to integrate Uniview with Powerdome®, so that it could run while Powerdome® is open. The interface took care of the corresponding access to the graphics board.

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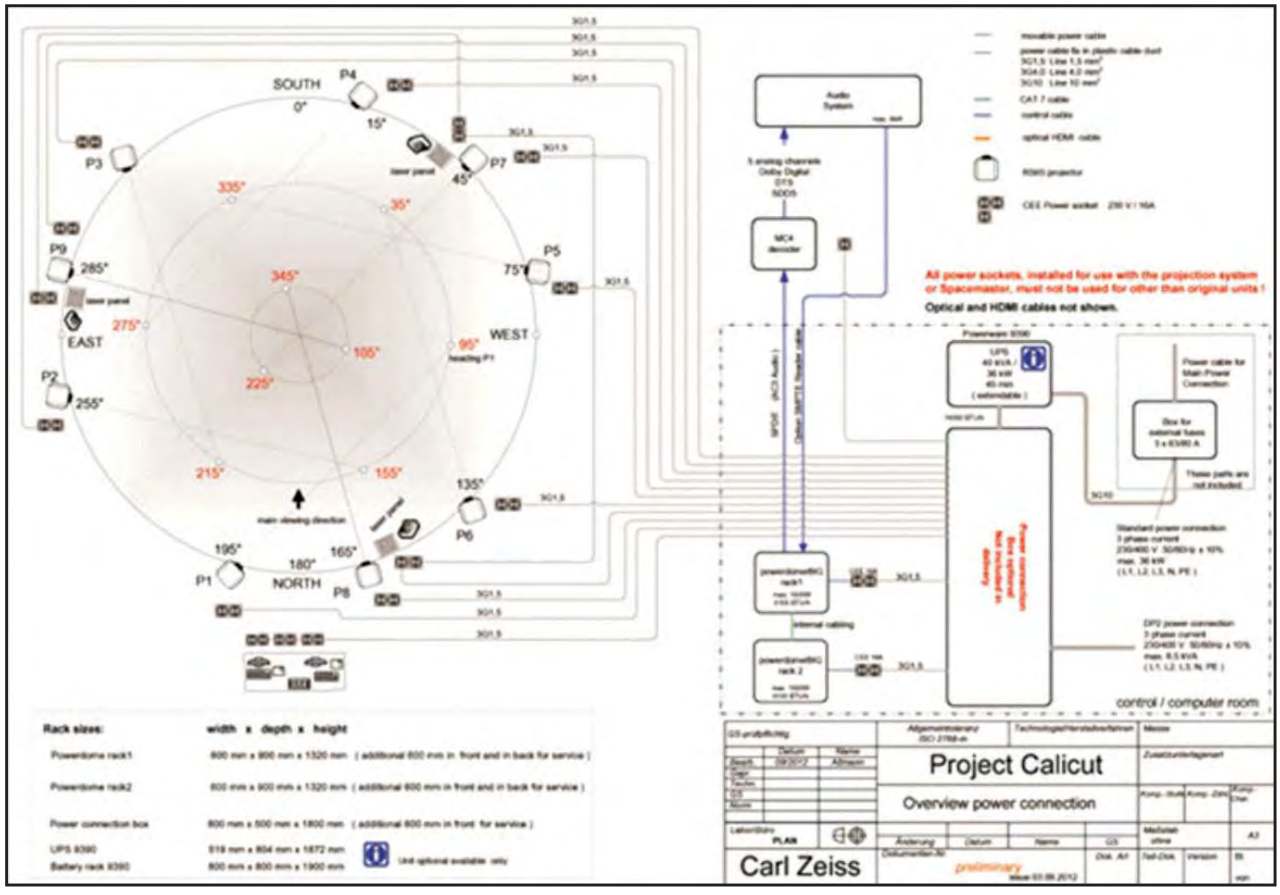

Figure 15. Projector arrangement for Shadow Free Projector

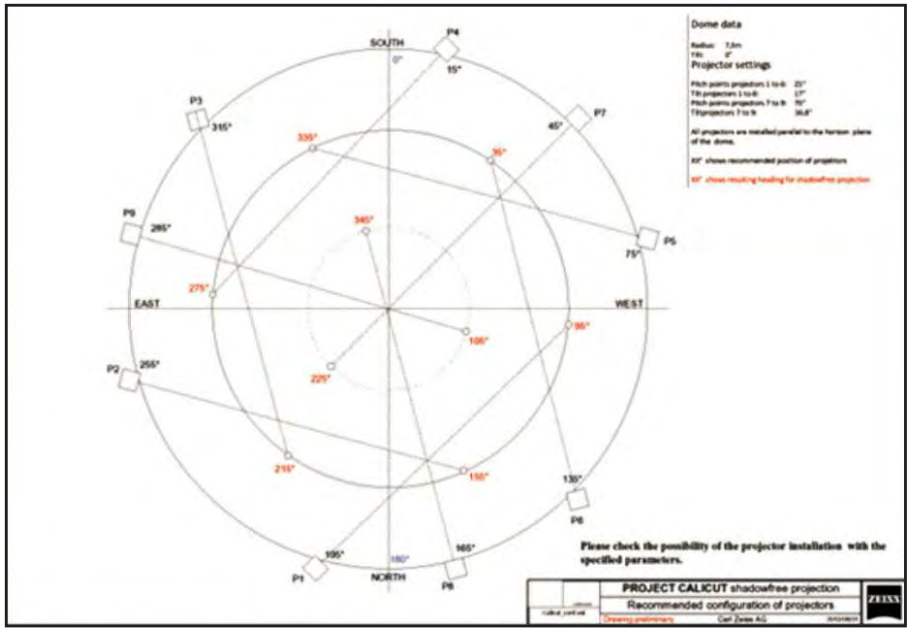

Figure 16. (i) : Shadow Free Geometry

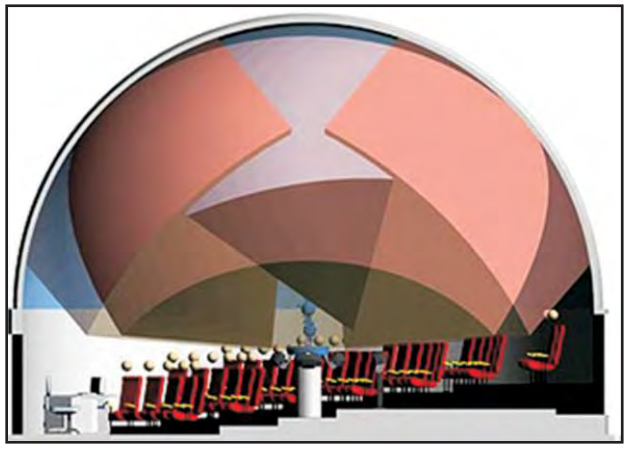

Figure 16. (ii) : Shadow Free Geometry

By means of the Powerdome - Uniview interface, live Uniview presentations were possible, as was the integration of Uniview presentations (sequences) in automatic shows.

Audio is an important component for a planetarium show presentation. Calicut Planetarium was equipped with 5.1 audio system with Denon audio processor and decoder. As a part of this upgrade, lot of other subsidiary works were undertaken which included fixing of lightning arrestor for the planetarium building, a new 40 KVA UPS, treatment of the dome wall with glass wool and gypsum board, laying of new floor tiles etc. The seating arrangement was altered from concentric seating to unidirectional seating. This was done to cater to the requirements of the new projection system.

With this major technical upgrade, Calicut planetarium became equipped with a hybrid projection system comprising nine channel digital Powerdome system with nine JVC DLA RS65 projectors and fully refurbished RFP DP2 Space Flight Opto-mechanical Projection system from Carl Zeiss, Jena, Germany.

In the remaining part of this paper we will discuss the in-house planetarium show developmental aspects and astronomy popularization as undertaken by this institution.

Planetarium Shows

The first three shows were procured from B M Birla Planetarium, Hyderabad. Then we started developing in-house planetarium shows. This involved development of script, visuals, music, recording and synchronizing. In a span of seventeen years of its history, the planetarium has conceptualized and developed as many as sixteen main shows with 'Dona and the universe' being its debut attempt.

Further, in order to make planetarium shows interesting to students from lower and upper primary sections who thronged the centre after winter vacations, and who were too young to follow the regular astronomy shows, we developed special shows using cartoon slides. This enabled them to have a better appreciation and understanding of basic astronomical ideas. Subsequently, eight new shows for primary school groups, two community-centric shows on RAMADAN and ONAM and one special show on Indian astronomy were developed. The variety of programmes offered at the centre has pushed the number of shows conducted in a day, and touched a record figure of nineteen shows in one day.

Hall of Astronomy

Astronomy through realistic sky simulation in the planetarium dome is a powerful method of mass education on the subject, which is running very successfully at the Calicut planetarium. But this planetarium has an added advantage - it is having a science centre attached to it. We took advantage of this and created a 4100 sq.ft gallery titled 'Hall of Astronomy' to complement the planetarium experience. The gallery has a rich display of visual information on various aspects of astronomy besides having thirty seven interactive models that explain various aspects of astronomy. The gallery was inaugurated on 7th March 2010 by Shri T. K. A. Nair, Principal Secretary to the then Prime Minister of INDIA.

Figure 17. Hall of Astronomy

The gallery is divided into four sections :

1. Pre Telescopic Era
2. Post Telescopic Era
3. Sun & Solar system
4. In Search of Cosmic Truth

Figure 18. Inside Hall of Astronomy

The pre telescopic era takes us through the antiquity when astronomers were mostly thinkers, philosophers and mathematicians. It depicts Aristotle's earth-centric universe (popularly called geocentric universe), Ptolemy's explanation of the complex motions of the planets through epicycles, and the Copernican model of the heliocentric universe.

Figure 19. Exhibiting Kepler's First Law of Planetary motion

Slowly the trend shifted towards observational astronomy. The most prominent figure of this era was Tycho Brahe. A prototype of the sextant developed by us following Tycho Brahe's design is displayed in the gallery. Brahe's young assistant Johannes Kepler, who carried out a thorough theoretical analysis of Tycho Brahe's observational data for 16 years, gave the world his famous laws of planetary motion. The gallery houses two working exhibits on Kepler's laws of planetary motion.

Figure 20. Galileo Galilei – Inside Astronomy Gallery

The post telescopic sections starts with homage to the architect of modern science, Galileo Galilei's revolutionary act of pointing the telescope to the sky and observing the details of heavenly objects changed our perception of the universe. Also in this section, there are a few models showing how reflectors and refractors work.

Modern telescopes evolved due to technological developments. Adaptive optics and Active optics are common terminology among professionals. There is an exhibit highlighting the principle behind these concepts. Radio telescope has opened a new window to the universe. Some celestial objects may not be observable in visible light but can be detected using radio telescope. A working model of a radio telescope in the gallery gives us insight into the working of these instruments.

In the section on Sun and solar system, topics relating to celestial events as observed from earth and facts relating to the sun and solar system are highlighted.

There are exhibits showing the effects of Precession and Nutation. Eclipses, transits and occultation are very dramatically exhibited through a participatory exhibit which people can play with and learn from about these celestial phenomena.

Figure 21. Electromechanical Orrery

An animated model of the sun discloses the internal structure of the sun. An electro mechanical model of the solar system (orrery) shows how the planets move around the sun. Also there is an exhibit which tells the visitors how much he or she would weigh in different planets. In addition, there is a working Foucault pendulum whose plane of oscillation changes with time. This in effect proves that the earth is rotating. The model on 'Celestial sphere' is another attraction in this section.

Coming to the last section, there are exhibits on pulsar, astronomical spectroscopy etc. There is also an 'Astro Quiz Corner' where people can test their knowledge in astronomy, and a computer kiosk that tells about the various career options available in India in the field of astronomy and astrophysics.

Astronomy Projects – Nurturing Young Minds in Astronomy

University Grant Commission (UGC) has rightly perceived that a scholar, whether in undergraduate studies or post graduate studies, will fully comprehend a concept if he/she undertakes a project in the subject. So, all courses under UGC have a project aspect in their curriculum of studies.

Innumerable request comes to this institution from students and teachers of diverse courses to undergo project work in astronomy. Having sophisticated telescopes, digital cameras and necessary technical expertise at its disposal, the centre took up this challenge too. The main task was to perceive novel project ideas in astronomy and astrophysics at various levels. As a result, nearly 300 students at various levels (School, UG, and PG) have carried out project works in this centre. The projects ranged from measuring the height of lunar mountains and crater depths, estimating the velocity of Galilean moons to determining the drift velocity of sun spots and much more.

One of the most highly rated projects is discussed here. It's measuring the height of the lunar mountain through image pixilation using MATLAB®.

Figure 22. Data for Measuring Lunar Mountain Pico

Here we take the shadow cast by mountains as observation parameter. Available astronomical data such as diameter of moon, distance from observer to moon at the time and date of measurement, latitude and longitude of the feature under consideration, etc. are used together with the measured length of the shadow of the mountain for the computation of the required results. For achieving this, an image of the area of the lunar surface containing the feature is captured using Canon 450D DSLR, Sony Camcorder and 11" CPC reflector; the image is then processed with RegiStax software, number of pixels of shadows counted, boundary errors eliminated using MATLAB® software, scale factor for the correspondence between one pixel and linear dimension in kilometers ascertained and then calculations made applying relevant formulae for results as well as for error corrections.

Astronomy Outreach Activities

Figure 23. (i) & (ii) : Sidewalk Astronomy

The centre has an enthusiastic Astronomy Club. The membership is open to all astronomy enthusiasts. Members include professors, scientists, teachers, engineers, medical practitioners, businessmen and farmers.

Figure 24. Astronomy Club Members measuring Diameter of Earth during a Venus Transit

Various astronomical activities like sky observations, seminars, workshops, visit to observatories, short and long term astronomy courses, astrophotography, astro drama, innovative astronomy outdoor experiments, workshops on telescope making, road side astronomy, citizen science astronomy, Messier marathon, eclipse & occultation watch, meteor shower astronomy etc. are arranged periodically. Further the planetarium conducts exhibitions in schools and engineering institutions with various astronomy related exhibits and desk top models, charts, slide shows, panels etc.

Figure 25. (i) & (ii) : Astrophotography

Members come and spend about two hours on weekends, reading and discussing astronomy. Also they learn how to handle telescopes and make observations. Calicut Planetarium also organizes summer and winter Astro camps.

Figure 26. Simulated Moon Surface Exhibition

Conclusion

Calicut planetarium has marched a long way ahead from its humble beginning. It can now boast of an astronomical heritage, an ultra modern hybrid planetarium and in-house technical expertise for utilizing the facility for public education on astronomy. The Powerdome® digital system enables full dome displays. Hybrid system facilitates simulation of real sky. Seasoned by experience, the RSC & Planetarium at Calicut is on the move to expand its boundaries of services to the nation in general and Malabar in particular for edutainment and also serious astronomy. This has resulted in attracting a record footfall of about five lakh (500,000) people to the Regional Science Centre and Planetarium at Calicut annually.

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Keyword Glossary

Sextant : Astronomical instrument to measure angular separation in the sky

Road Side Astronomy : Using telescope in public places to show astronomical objects in the sky through telescopes to passer-by.

MATLAB® : A proprietary commercial software for matrix manipulation

PC : Personnel Computer

GUI : Graphical User Interface

Additional Information

I. As per the decision of Govt. of India vide its Office Memorandum (OM) dated 29.11.2002 and subsequent OM dated 08.01.2003 erstwhile CEDTI (Centre for Electronics Design & Technology of India) Centres (except Mohali Centre) and Regional Computer Centres(RCCs) Kolkata and Chandigarh have been merged with NIELIT (National Institute of Electronics and Information Technology) w.e.f. 14.12.2002, which is an autonomous body under Ministry of Information Technology, Government of India.

Accordingly, the erstwhile CEDTI Centres (except Mohali Centre) and RCCs have been renamed as National Institute of Electronics and Information Technology (NIELIT) (formerly DOEACC Society).

II. Web site of RSC & Planetarium, Calicut : www.rscpcalicut.org
III. Virtual visit to Hall of Astronomy, RSCP, Calicut: http://p4panorama.com/panos/planetarium/index.html

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Social Inclusiveness of Indian Science Centres and Museums : A Snapshot through Case Studies (Part-III)

Subhabrata Chaudhuri

Abstract

Currently, Science Museums and Centres in India are in a process of transformation in response to social and economic imperatives at local, national and global levels. As mentioned earlier, several models of impact studies have been envisaged for European and American counterparts; however, these have been seldom attempted in Indian scenario except a few individual reporting [Hoyt et al, 2011; Rautela et al, 2011; Dutta Choudhury, 2011; Patairiya et al, 2010]. Social inclusiveness in terms of visitor turnout, participation of people with special needs, role of this sector in addressing the needs of the locals especially in organising personal growth has been dwelt upon in the Part-II of this series. In this last and final part, certain aspects of inclusion issues, especially those of financial accessibility of Indian Science Museums and Centres, have primarily been attempted.

Introduction

Impact studies, because of some reasons or the other, have turned out to be a sustained area of interest among the museum fraternity for years. Literature studies indicate that it was during early eighties of the last century, such studies, primarily on individual institution basis, were at times undertaken, that too, mainly in USA and partly in UK. But the same on the science centre and museum arena was reported inthe laterstage (Falk and Dierking 1992,Garnett 2002; Groves 2005;Falk & Sheppard, 2006; Friedman, 2007, 2008; Persson, 2000, 2011; Falk& Needham, 2011,Falk, Dierking, Needham, &Prendergast,2014). Today, this sector globally is confronting a host of issues- the global economic downturn, the question of welfare systems, waning governmental support to such institutions, the digital shift and change in people's preference, emergence of entertainment industry and so on. This results in difficulties to assess the economic and institutional impacts of this sector despite the fact that the number of museums has increased substantially in the last few decades; they are more accessible with modern outfits; they are more networked, inclusive resorting to niche marketing strategies by way of becoming participatory to the local community. They are adept at handling aspirations of diverse audiences nowadays. The multidimensional and multi-faceted value (personal, social, cultural, economic, environmental etc.), this sector contribute to generate and spread to the society, is a matter of contemporary interests.

Rationale

With the change of psychographic terrain of modern visitor minds, visits to Science Museums and Centres are becoming an important leisure, holiday and non-formal learning activity. Visitors in the role of consumers spend hefty amounts visiting museums, both in terms of entry fee, other tickets for important facilities like 3D programme, Space theatre etc. and expenses in souvenir shops and food outlets. These expenditures have a strong effect on local economies, especially for those in popular tourist areas. Notwithstanding diverse approach in respect of content, size, age and institutional forms, Indian Science Museums and Centres share some particularities and similar functionalities. In economic parlance, such an institution may be looked at as an economic unit providing certain services. To be more precise, it connotes to a relationship between the inputs (exhibits, manpower etc.) and output measured, e.g., revenue. On the other hand, the effect of these institutions on the local economy leaves room for extensive analysis in terms of generation of employment, value addition to other sectors.

Studies in Indian context indicate that the entry fee in Indian socio-economic scenario somewhatregulates the flow of visitors of a particular area in the science centres and museums.At times, a Science Centre (or Museum) arranges to develop/host new exhibitions or conduct special programmes, and takes recourse to concessional rates for organised groups to augment visitation figures, even though econometric estimates for a large number of different museums in various countries suggest that the demand for museum services is price inelastic.

Using US data from the Museum Survey of 1989 (Luksetich and Patridge, 1997), it is estimated that price elasticity demand functions for different types of museums range from - 0.12 to - 0.26, depending on the type of museums whereas the same for cinema visits, live performing art, long drive in cars in US being -0.87, between -0.4 to -0.9 and -0.31 respectively. However zoos, science museums and natural history museums showed the largest price sensitivity, probably due to greater competition from the other leisure activities. Overall, the low price inelasticities suggest that museums could generate significance increases in revenues through increasing admission fees.

Apart from price elasticity issues, however, the question of opportunity cost of time comes out to be an issue to reckon with persons from higher income group or those who are self-employed, the opportunity cost of time is higher than for people of low income group or those on fixed working hours as they are expected to visit museums more often, if all other conditions remain the same. In case of tourists as visitors, the opportunity costs of time are likely to be lower than the local population, since they have the express purpose of visiting the museum.

While elucidating on the economic aspects of science centres, the issue of alternative leisure activities such as going to some cultural events, taking part in any other social activities like in sports, visiting shopping malls or amusement parks cannot be ruled out. Even within the same organisation, one science centre may be an alternative destination to the other. Within National Council of Science Museums (NCSM), two major units Science City and BITM are situated in the same city Kolkata. The crux issue is whether these two organisations are supplementary or complementary to each other. Apart from the aspect of complementary costs like the costs of travel, accommodation, may be meals etc., income of the local population is another determinant affecting the demand for museum visits.

Econometric estimates show an income elastic demand favouring more visitation pattern for higher income groups (Withers 1980), even though, as referred to earlier, the rising opportunity cost of time goes hand-in-hand with higher income. There is also a high co-relation between income and education on one hand, and visitation on the other. Better educated people, in absence of gratuitous/proactive services of the museums, are unlikely to derive more benefits from Science Museums and Centres and those lower ineducation (Gray, 1998). This factor is more pronounced in art and history museums than with Science &Technology Museums and Centres.

Other than the above, Science Museums and Centres cater to the social demand creating social value which cannot be reflected in monetary terms. While people do value the possibility of enjoying or discuss issues in such a setting with beneficial social affects, these institutions also in certain instances produce negative external effects like traffic congestion, noise etc., through visitor movements on the local community. Yet, it cannot be gainsaid that Science Museums and Centres in India play important roles as economic actors by creating additional jobs, vocation for local people and commercial revenue particularly in the food industries that leads multiplier effect results. The area adjoining Science City, Kolkata along the Eastern Metropolitan (EM) Bypass has been turned into one of the important zones with numerous economic activities like hotels, institutions, shopping malls, hospitals and so on in Kolkata only after Science City set the ball rolling with its inauguration in the year 1997. Prices of land along the EM Bypass have gone up manifold than compared to those of any other locality in Kolkata. This leads to the iconic multipler effects as far as economic activities of a science-centre-type-institution in a larger scale with components of edutainment are concerned. It is worthwhile to make mentionof Seaman, 2002 in this context, who wrote in the article "CVM vs. Economic impact: substitutes or complements" that the so-called impact studies measuring additional market effects created go down well very much with politicians and administrators as they seek to find reasons for spending money on this sector.

Case Study

At the backdrop of all the above referred aspects of a complex issue, we attempted to explore the social inclusivity of a set of 39 science museums, science centres, natural history museums and planetariums (Annexure-A) dotted all over the country from economic standpoint through questionnaire survey (Annexure-B) and in some instances, through in-situ

analysis of current practices. While doing so, we take into consideration the struggle of about 27 crore (270 million) Indians, out of 123 crore (1230 million), living below the poverty line. Finance is essentially the most basic constraint to the majority of the Indian population. So the economic dimensions have become more and more relevant to the cultural sector in India, more precisely to the Science Museums and Centres in this country which are unlike the collection based museum where conservation is the key. On the contrary, as an extension of classroom engagement in a non-formal setting, the learning outcomes, or more precisely, impact assessments of this sector have been the subject of some of the publications in recent times using different methodologies (Rautela, G S, 2000). But the evaluation of socio-economic impact or financial inclusiveness has not yet been evaluated, or at least reported.

The economic impact of a science centre traces the flow and level of spending that can be attributed to the activities of a science centre. It also estimates the economic impact of the science centre on a defined economic region over a particular time period. This is made up of primary and secondary impacts. Direct impact, among other things, is made up of spending by the science centre itself, and of the jobs that it provides; spending by people who visit the region in order to go to the science centre. Indirect impact refers to extra business generated for suppliers of goods and services to the science centre and its visitors; and the induced impact of increased 'consumption spending' in the region as a result of larger wages and increased organisational revenue being returned to the local economy by the science centre and their suppliers.

Results & Discussion

I focused my study on financial inclusiveness and economic impact of the science museum and science centre sector in India stemming from its diverse activities & projects and as seen (and measured) as a contribution to the local economy in a multi-faceted manner in terms of :

- Ticket rates vs. Per Day Per Capita Income
- Entry Fee for Student Visitors'
- Revenue Growth in the last 5 years
- Expenditure (Budget) Growth in the last 5 years
- Programmes for Socio-economic Growth of the Locality in the last 5 years
- Active and Passive Influence on Local Economy (multiplier effects)

Study of financial inclusion on the basis of entry fee, fees for other facilities and per day per capita income of local population of the institutions under survey :

Mr K. C. Chakrabarty, former Deputy Governor, Reserve Bank of India, defined financial inclusion as "the process of ensuring access to appropriate financial products and services needed by vulnerable groups such as weaker sections and low-income groups at an affordable cost in a fair and transparent manner by mainstream institutional players." But in science centres, financial inclusion broadly means accessibility of the centre to the people from all the economic strata of the society.

On analysis of the information compiled in the Table 1, Table 1.1 and Table 1.2 (page no. 44, 45), we may conclude that in 26 out of 38 Indian Science Museums, Science Centres and Planetariums, it is found that the local people spend approximately within 10% or less of their per day per capita income for effecting a family visit only as entry fee (i.e. only to see all the non-ticketed facilities) and within 30% of their per day per capita (pdpc) income for effecting a family visit including availing of all other facilities of those organizations which are in ticketing zones (like 3D, Planetarium etc.) respectively.

On the Basis of Entry Fees

On an average, a person needs to spend 10.21% per day per capita (pdpc) income of the state he/she belongs to for just entering into the science centre/museum premises for visiting non-ticketed facilities. The measure of dispersion (standard deviation) 7.72% indicates that the entry fee spreads out over a large range. For example, entry at NMNH (both in Bhubaneswar and Bhopal) is free whereas PGSC charges of Rs. 75/- and Guwahati Planetarium Rs. 30/- which are found to be quite on the higher side when compared with the per day per capita income of the respective places (36% of pdpc income).

On the Basis of Entire range of Fees (including Entry Fees)

There are 7 science centres (out of 38) in India where costs of availing of all facilities including entry fees are extremely high. These centres charge more than 50% of per day per capita (pdpc) income of the corresponding states (local income). Along with entry fee, a person spends on an average 27.82% of per day per capita income for availing all the facilities in an Indian Science Centre. But the most interesting part is the measure of dispersion (standard deviation) which being remarkably high at 23.68% indicates that this entire range of fees spreads out over a large range.

Emerging Scenario due to New Fee Structure (to be introduced from June 1, 2014)

But when the revised entry fee structure in NCSM science centres, which became effective from June 1, 2014 is considered, as presented in the Table 1.3, we find that the average entry fee is going to increase by 4.18% (from 10.21% to 14.39%) of per day per capita (pdpc) income.

Burden of Fees on Students

Table 1.4 (in page 46) reveals that a student on an average spends 1.8 % of per day per capita (pdpc) income of the respective state only for entering to the Indian science centres/ museums and his/her average spending for availing all the facilities along with entry fee is 4.26% of pdpc income. This result indicates discomfiture so far as its telling effect on the visitation figure of the student groups especially from the lower rung of the society is concerned. After all student community forms the primary target marketing zone for Indian Science Centres/Museums.

Financial Inclusion in other Art, Culture Institution (based on entry ticket)

Kolkata being the cultural capital of India, we selected the model of Kolkata. We chose 3 model institutions- Indian Museum (Kolkata), Alipore Zoo (Zoological Garden, Kolkata) and INOX (a Cinema Hall network chain, the least price of a ticket has been considered).From Table 1.5, we may readily conclude that visiting INOX theatre for a movie is the costliest of all enjoyment options in Kolkata, as compared to other amusement zone like a Zoo or a Museum. Another interesting scenario should not escape one's notice that Alipore Zoo is costlier than visiting BITM. Moreover, enjoying all the facilities of Science City, Kolkata is less costly than seeing a movie in INOX theatre.

Sl.No	Centre Name	Entry Fee	Other Fees	A Family Spends (entry only)	A Family Spends (including other facilities)	Per capita income of the State (2010-2011)	Per day per capita income (=PCI/365)	% of per day income of 4 persons, spending only for entry	% of per day income, spending including other facilities
xx	xx	Per head	Per head	(2 adults + 2 child)	(2 adults + 2 child)	(at current price)	xx	xx	xx
1.	BITM	15	52	60	268	48536	133	12	51
2.	NSCD	30	20	120	200	150653	413	8	13
3.	VITM	30	27	120	228	60946	167	18	35
4.	NSCM	30	70	120	400	83471	229	14	44
5.	SCTY	30	70	120	400	48536	133	23	76
6.	RSCL	15	45	60	240	26355	73	21	83
7.	RSCBBSR	10	17	40	108	40412	111	10	25
8.	RSCG	20	50	80	280	30569	84	24	84
9.	RSCNAG	10	45	40	220	83471	229	5	25
10.	RSCBHO	10	12	40	88	32222	89	12	25
11.	RSCCALI	10	35	40	180	71434	196	6	23

Sl.No	Centre Name	Entry Fee	Other Fees	A Family Spends (entry only)	A Family Spends (including other facilities)	Per capita income of the State (2010-2011)	Per day per capita income (=PCI/365)	% of per day income of 4 persons, spending only for entry	% of per day income, spending including other facilities
12.	RSCTIRU	10	27	40	148	62912	173	6	22
13.	SSCPAT	10	19	40	116	20708	57	18	51
14.	KPSC	20	20	80	160	94680	260	8	16
15.	NBSC	10	24	40	136	48536	133	8	26
16.	GSC	10	30	40	160	168572	462	3	9
17.	BURSC	5	15	20	80	48536	133	4	16
18.	DSCDGA	10	31	40	164	48536	133	8	31
19.	DSCDKL	5	4	20	36	40412	111	5	9
20.	DSCGUL	10	25	40	140	60946	167	6	21
21.	DSCDHAR	3	13	12	64	75115	206	2	8
22.	DSCTIRU	10	25	40	140	72993	200	5	18
23.	DSCPURU	5	18	20	92	48536	133	4	18
24.	SCPB	10	25	40	140	76883	211	5	17
25.	APSC	10	5	40	60	55789	153	7	10
26.	NAGSC	10	0	40	40	52643	145	7	7
27.	SHISC	10	0	40	40	50427	139	8	8
28.	SIKSC	10	0	40	40	81159	223	5	5
29.	MANSC	5	0	20	20	29684	82	7	7
30.	SUKACK	10	70	40	320	44965	124	9	65
31.	**PGSC**	**75**	**220**	**300**	**1180**	**128634**	**353**	**22**	**84**
32.	TNSTC	20	30	80	200	72993	200	10	25
33.	BMPIL	10	0	40	40	34042	94	11	11
34.	RMNHBHO	0	0	0	0	32222	89	0	0
35.	RMNHBBSR	0	0	0	0	40412	111	0	0
36.	PSPBBSR	25	30	100	220	40412	111	23	50
37.	SCSOLA	10	30	40	160	83471	229	5	18
38.	MSPLA	16	0	64	64	48536	133	13	13
39.	GUWPLA	30	0	120	120	30569	84	36	36

Table 1

Spends only for entry (% of per day income of 4 persons)		
0-5%	12	
6-10%	14	
11-15%	5	
16-20%	2	Average spending for entry : 10.21% of pdpc
21-25%	5	
26-30%	0	
31-35%	0	Standard Deviation : 7.72% of pdpc
36-40%	1	

Table 1.1

Spending for availing other facilities (% of per day income of 4 persons)		
0-10%	9	
11-20%	9	
21-30%	8	
31-40%	3	
41-50%	2	
51-60%	2	Average Spending for availing all the facilities : 27.82% of pdpc
61-70%	1	
71-80%	1	Standard Deviation is: 23.68% of pdpc
81-90%	3	

Table 1.2

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Sl. No.	Centre Name	Entry Fee	A Family Spends on Entry Only	Per capita income of the State (2010-2011)	Per day per capita income	% of per day income, spending only for entry
xx	xx	xx	Family = 2 adults + 2 children	(at current price)	PDPCI =PCI/365	xx
1.	BITM	40	160	48536	133	31
2.	NSCD	40	160	150653	413	10
3.	VITM	40	160	60946	167	24
4.	NSCM	40	160	83471	229	18
5.	SCTY	40	160	48536	133	31
6.	RSCL	20	80	26355	73	28
7.	RSCBBSR	20	80	40412	111	19
8.	RSCG	20	80	30569	84	24
9.	RSCNAG	20	80	83471	229	9
10.	RSCBHO	20	80	32222	89	23
11.	RSCCALI	20	80	71434	196	11
12.	RSCTIRU	20	80	62912	173	12
13.	SSCPAT	15	60	20708	57	27
14.	KPSC	15	60	94680	260	6
15.	NBSC	15	60	48536	133	12
16.	GSC	15	60	168572	462	4
17.	BURSC	10	40	48536	133	8
18.	DSCDGA	10	40	48536	133	8
19.	DSCDKL	10	40	40412	111	10
20.	DSCGUL	10	40	60946	167	6
21.	DSCDHAR	10	40	75115	206	5
22.	DSCTIRU	10	40	72993	200	5
23.	DSCPURU	10	40	48536	133	8

Table 1.3

Sl.No	Centre Name	Entry Fee (Students)	Other Fees (Students)	Total Fees
1.	BITM	7.00	36.00	43.00
2.	NSCD	15.00	10.00	25.00
3.	VITM	15.00	17.00	32.00
4.	NSCM	15.00	25.00	40.00
5.	SCTY	10.00	55.00	65.00
6.	RSCL	10.00	30.00	40.00
7.	RSCBBSR	5.00	9.00	14.00
8.	RSCG	10.00	25.00	35.00
9.	RSCNAG	5.00	25.00	30.00
10.	RSCBHO	5.00	07.00	12.00
11.	RSCCALI	5.00	20.00	25.00
12.	RSCTIRU	5.00	xx	

Table 1.4

Sl.No	Centre Name	Entry Fee (Students)	Other Fees (Students)	Total Fees
13.	SSCPAT	10.00	20.00	30.00
14.	KPSC	10.00	nn	xx
15.	NBSC	5.00	14.00	19.00
16.	GSC	2.00	13.00	15.00
17.	BURSC	2.00	26.00	28.00
18.	DSCDGA	2.00	4.00	6.00
19.	DSCDKL	5.00	15.00	20.00
20.	DSCGUL	1.00	nn	
21.	DSCDHAR	5.00	15.00	20.00
22.	DSCTIRU	2.00	12.00	14.00
23.	DSCPURU	5.00	20.00	25.00
24.	SCPB	5.00	00.00	05.00
25.	APSC	5.00	5.00	10.00
26.	NAGSC	5.00	0.00	05.00
27.	SHISC	5.00	0.00	05.00
28.	SIKSC	5.00	0.00	05.00
29.	MANSC	3.00	0.00	03.00
30.	SUKACK	5.00	35.00	40.00
31.	**PGSC**	50	175	225.00
32.	TNSTC	25.00	nn	
33.	BMPIL	05.00	0.00	05.00
34.	RMNHBHO	0.00	0.00	0.00
35.	RMNHBBSR	0.00	0.00	0.00
36.	PSPBBSR	15.00	20.00	40.00
37.	SCSOLA	5.00	15.00	20.00
38.	MSPLA	08.00	0.00	08.00
39.	GUWPLA	15.00	0.00	15.00

Table 1.4

Name	Type	Entry Fee	Per capita income of the State (2010-2011)	Per day per capita income	% of per day income, spending only for entry
ALIPORE ZOO	Zoo	20	48536	133	16
INDIAN MUSEUM	Art/Nat. Museum	10	48536	133	8
INOX MOVIES,KOL	Cinema Hall	150	48536	133	113

Table 1.5

i) Financial Impact by the means of Growth of Budget (expenditure) and Revenue

Growth of NCSM Budget (Expenditure)				
F-Y	Plan	Non Plan	Total	Growth %
2009-2010	2316.03	4352.35	6668.38	xx
2010-2011	2735.92	4306.27	7042.19	5.61
2011-2012	3211.58	4620.81	7832.39	11.23
2012-2013	3252.50	5342.35	8594.85	9.74
2013-2014	3068.33	5733.71	8802.04	2.42
Average Growth of Budget over a period of 5 years (F -Y)				-------- 6.34%

Table 2.1

Revenue Growth of NCSM		
F-Y	Revenue	Growth%
2009-2010	1036.80	xx
2010-2011	1280.44	23.5
2011-2012	1525.17	19.2
2012-2013	1676.28	10
2013-2014	1770.00	5.6
Average Revenue Growth of NCSM over a period of 5 years (F-Y) ------- 14.2%		

Table 2.2

From Table 2.1 and 2.2, it is discernible that while expenditure grew at a rate of 6.34% per year, the revenue has grown @ 14.2% per year over a period of 5 years from 2009-10 to 2013-14. A major growth in revenue can be seen during 2009-10 to 2011-12at 23.5% and 19.2% respectively. However, this growth is found to be marginal in the last two financial years. In fact, in 2013-14it grows only 5.6% as a sequel to certain economic factors, like inflation due to uncontrolled price rise of essential commodities, dipping FDI, widening fiscal deficit etc. affecting the country.

ii) Financial inclusion by the means of socio-economic impact study

Socio-economic impact includes programmes targeted to personal growth, community empowerment and programmes aimed at tackling unemployment of the local people etc. study of the local economic background and direct & indirect employment opportunities created by the Science Museums and Centres.

a) Programmes on 'Socio-economic Growth' in last five years

Nature of Programme	No. of Science Centre
Personal Growth	17
Community empowerment	19
Tackling Unemployment	10

Table 3.1

From the Table 3.1, we can say that about 50% of the surveyed Indian science centres have conducted programmes on personal growth and community empowerment. But when it comes to programmes envisaged for tackling unemployment, this percentage substantially drops;only 25% of the centres/museums conducted such programmes in the last 5 years.

Sl. No.	Name of the Centre	Detail of the Programme on Tackling Unemployment
01.	Birla Industrial & Technological Museum, Kolkata	• Hardware & Networking Course for Unemployed Youths • Hydroponics workshop for housewives and entrepreneurs • Origami - home decoration with paper made products • Empowerment programmes with prisoners
02.	Visvesvaraya Industrial and Technological Museum, Bangaluru	• 'Channapatna Toy making Training program' • Batik and block printing training program for youth. • Screen printing program for youth. • Household cleaning material preparation.
03.	Regional Science Centre, Tirupati	• Entrepreneurship programme for women in Agriculture, exclusively for girls. • Programmes on Floral Decoration, Kitchen Garden and Vermi Culture on various occasions in the past 5 years.
04.	District Science Centre, Dharampur	• Meson training programme for school dropouts. • Soft toys making workshop for housewives. • Computer training programmes. • Jardosi training programme for housewives.
05.	District Science Centre, Tirunelvelli	• Special 'Awareness Programme' for the rural youth in collaboration with Nehru Yuva Kendra, Tirunelveli on various Technical Self Employment Schemes for the rural youth. • An interactive student motivation programme, "Passionate Yourself" on "Goal Setting".
06.	Science Centre, Port Blair	1. "Meet the Pilot", Workshop on Article Writing with special reference to Science Articles 2. Workshop on making of Films specially designed to tackle the unemployment problems.
07.	Sikkim Science Centre	

	Training	Collaborating Institution	Beneficiary number
a)	Training on Agro Technique, Macro propagation, Seasoning & Value Addition on Bambo	(i) Rain Forest Research Institute, Jorhat, Assam (ii) Cane & Bamboo Technology Centre, Guwahati	80 (Capacity Building Programme for progressive farmers)
b)	Capacity Building & Training Programme on Food/ Vegetables & Fruit Processing Central Food Technology Research Institute, Mysore	Central Food Technology Research Institute, Mysore	80 (Capacity building programme for rural women)

Table 3.1.1

Sl. No.	Name of the Centre	Detail of the Programme on Tackling Unemployment			
		c)	Capacity Building Programme on Agrotechnique & Value Addition of Medicinal & Aromatic Plants	Central Institute of Medicinal & Aromatic Plant (CIMAP) Lucknow Institute of Himalayan Bio Resources & Technology, Palampur, Himachal Pradesh	40 (Capacity building programme for progressive farmers and unemployed youth & entrepreneurs)
08.	Tamilnadu Science and Technology Centre	• Career counselling programmes are being organized periodically throughout the State. • Training Programmes on Java and Open source software su ch as Linux and other software to make the engineering graduates employable.			
09.	RMNH, Bhubaneswar	• In-house and outreach programmes include empowerment programmes for differently abled peoples like physically challenged, mentally challenged, hearing impaired and visually challenged through creative activities like painting, clay modelling, touch, feel and learn, singing activities etc. and for fisherman community.			
10.	Solapur Science Centre	• Women self-help group targeted programme sto provide general information about computers and internet, how to book and take a gas connection and many online related facilities ,who are otherwise not aware of these.They are expected to use such that may fetch employment/dividends out of this exposure.			

Table 3.1.1

On scrutiny of the Table 3.1.1, which elaborated on the programmes aimed at tackling the problems of unemployment, it may be stated that Indian Science Centres/Museums do not have any common framework for such programmes. However, they rely on local scenario for framing such programmes. For example, DSC, Dharampur, located at one of the Asia's largest tribal belts, designs such programmes in a very interesting manner. You will find that the Centre conducts 'Meson training' programme for 'school drop-outs', arranges 'Jardosi' (an internationally popular designer saree produced locally) and Soft-toy-making workshops for housewives as well as conducts Computer training programmes.

Actual financial impacts of these programmes are yet to be assessed among the local population. But apart from the programmes on 'tackling unemployment' (Table 3.1.1), if we go through the training curriculum of these centres individually, we can conclude that these are aimed at personal growth and community empowerment for grooming people to become successful in professional career.

b) Location & Local Economic Background

When studying the location and local economic background (as reported by the Heads of respective institutions) of the Indian Science Museumsand Centres, it is found that majority of them are city or town centric. Even some of the rural science centres are situated at tourist places (Table 3.2.1) and 29 out of 38 centres are situated in mixed economy zones (Table 3.2.2).

Metro City	6
City (State Capital)	9
City/Urban	4
Suburban	9
Rural	3
Tourist Place	5

Table 3.2.1

Local Economy

Agrarian	6
Mixed	29
Business	2
Others	1

Table 3.2.2

From Table 3.2.1 and Table 3.2.2, we may conclude that Indian Science Centre need to have more rural penetration. It may be in the form of rural extension wing. Primarily this may be done for a certain period of time, as we would do with MSE programmes.

Conclusion

The impact studies on economic issues for the Science Museum sector, that too in a pluralistic republic like India that thrives on diversity at all fronts, is, in fact, a mammoth task in terms of consideration and consolidation of specific local economic issues of each establishment, choice of appropriate econometric analysis to be put on board for interpreting data, and on the top of all, time and costs.

Studies based on monoculture of societal settings abroad should not be adopted in a diverse country like India, even though it is an undeniable fact that each set-up is an economic unit unto itself with input-output components having a moderate influence of price elasticity of demand in diverse scenario, as discussed earlier.

The findings of this study document the broad-based economic inclusiveness of Indian Science Museums and Centres in the current context. However, the multiplier effects of this impact on the local, zonal, regional and national economy may be explored in proper perspectives in the next phase. Even though the study is based primarily on entry fees and fees for visiting other facilities, it is important to mention here that there are globally large differences of opinions amongst museums in the way they set the entrance fees. There are raging debates whether or not to charge (O'Hagan, 1995; Heilbrun and Gray, 2001; Bailey and Falconer, 1998). Still today, most of the British museums don't charge their visitors. Even in the United States some national museums do not levy an explicit entrance fee. Some positive externalities connected with this sector, as dwelled upon in this article in the preceding sections, may put forward the arguments in favour of free admission of student community which forms the major chunk of clientele base of Indian Science Museums and Centres.

Finally it won't be out of place to mention certain words of caution in respect of impact studies, especially those dealing with economic aspects which often tend to focus on the wrong issues. It needs to be kept in mind that the raison d'être of museums, including the Science Museums and Centres, is to produce the unique service of providing a certain type of cultural experience to its visitors as well as providing the benefits to all other stakeholders as referred to the above. After all, a museum's primary task, as a component of creative industry, is not to essentially support the economy per se; there are much better avenues to achieve that goal.

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Annexure A

Name of the Participating Indian Science Centres, Museums & Planetariums

APSC	-	Arunachal Pradesh Science Centre
BMPIL	-	Birla Museum, Pilani
BITM	-	Birla Industrial & Technological Museum
BURSC	-	Science Centre, Burdwan
DSCDGA	-	Digha Science Centre & National Science Camp
DSCDHAR	-	District Science Centre, Dharampur
DSCDKL	-	Dhenkanal Science Centre
DSCGUL	-	District Science Centre, Gulbarga
MANSC	-	Manipur Science Centre (Department of Science & Technology, Govt. of Manipur)
DSCPURU	-	District Science Centre, Purulia
DSCTIRU	-	District Science Centre, Tirunelveli
GUWPLA	-	Guwahati Planetarium
GSC	-	Goa Science Centre
KPSC	-	Kurukshetra Panorama & Science Centre
MSPSSC	-	Meghnad Saha Planetarium & Space Science Centre
NSCM	-	Nehru Science Centre, Mumbai
NAGSC	-	Nagaland Science Centre
NBSC	-	North Bengal Science Centre
NSCD	-	National Science Centre, Delhi
PSPBBSR	-	Pathani Samanta Planetarium, Bhubaneswar
PGSC	-	Pushpa Gujral Science City
RMNHBBSR	-	Regional Museum of Natural History, Bhubaneswar
RMNHBHO	-	Regional Museum of Natural History, Bhopal
RSCBHO	-	Regional Science Centre, Bhopal
RSCBBSR	-	Regional Science Centre, Bhubaneswar
RSCCALI	-	Regional Science Centre & Planetarium, Calicut
RSCG	-	Regional Science Centre, Guwahati
RSCL	-	Regional Science City, Lucknow
RSCNAG	-	Raman Science Centre & Planetarium, Nagpur
RSCT	-	Regional Science Centre, Tirupati
SCPB	-	Science Centre, Port Blair
SSC	-	Sikkim Science Centre
SSCP	-	Shrikrishna Science Centre, Patna
SCTY	-	Science City, Kolkata
SHISC	-	Shillong Science Centre, Meghalaya
SCSOLA	-	Sholapur Science Centre
SUKACK	-	Sukanta Academy, Agartala
TNSTC	-	Tamilnadu Science & Technology Centre
VITM	-	Visvesvaraya Industrial & Technological Museum

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Questionnaire Annexure – B

Institutional Information

Name:

Address:

State: Country: PIN/ZIP:

Name of the Head of the Institute/ CEO :

Position:

Phone: Email:

1. Please tick which ONE of the following that BEST describes your organization:
   a. Science Center [ ]
   b. Science Museum [ ]
   c. Planetarium [ ]
   d. Natural History Museum [ ]
   e. Others [ ] Please specify:

2. In which year your institution was first opened regularly to the public? [ ]

3. Does your institution charge a general admission fee?
   1. Yes [ ]
   2. No [ ]

4. How much floor space in your institution is for public use?
   (Exclude areas such as offices, workshops, storage space etc.)
   Indoor : _____ square metres
   Outdoor : _____ square metres
   Note: (1000 sq feet = 93 sq metres, if your institution has more than one building / site, please show combined floor area)
   Number of days in a year that your institute remains open:

Area of Your Centre

5. **How do you characterize the area of your centre:** Is it situated in a cosmopolitan city area or in a tourist spot or in a suburban or rural area?

6. **What is your observation on the financial and social condition of the local population of the surrounding area?** (e.g. whether agrarian economy, surrounded by any ethnic community)

Financial (Please tick)		Social Resolution	
1) Agrarian Economy	[ ]	1) Major Linguist group:	
2) Business driven economy	[ ]	2) Ethnic Group(s) (if any):	
3) Mixed Economy	[ ]	3) Mixed population group:	
4) Others (specify)	[ ]	4) Others (specify) :	

Your Fee structure

7. **What is your entry-gate fee?**

8. **What are the other facilities with additional fees?** *(e.g – Taramandal (planetarium), Science Demonstration, 3D Theatre etc.)*

9. **Do you have any other avenue of income?** *(e.g – Renting of Auditorium, rentable picnic area in garden etc.)*

(Please give detail for general public, organized student group separately)

Programmes

10. **Have you ever conducted any programme for Personal Growth and Development in last five years? Please give a brief description.**
(The Programmes are supposed to make significant differences in the lives of individuals at risk of financial, intellectual and social disadvantages. Expected outcomes include enhanced self-esteem, confidence and creativity, which, in turn, have helped people develop more active, fulfilled and social lives)
11. **Have you ever conducted any programme for community empowerment in last five years? Give a brief account.**
12. **Have you ever conducted any programme directed towards tackling the problem of unemployment? Please elaborate.**

Publicity

13. **What is your publicity budget?**

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Presenting Abstract Ideas in Science Museums/Centres : Mathematics Gallery of BITM, Kolkata - A Case Study

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Abstract

Mathematical concepts and techniques allow us to see hidden patterns in the various phenomena happening around us in the natural world and in human societies. As a curricular subject, mathematics evokes strong emotions from its learners – loved by some and hated by most. The general perception is that mathematics is very abstract, hard to visualize and difficult to connect to physical realities. The new gallery on 'Mathematics' at BITM was established in the year 2010 to change this notion about mathematics. This article provides a brief overview of the gallery and how it explains various abstract mathematical concepts through interactive models and hands-on activities to help young learners enjoy mathematics in a playful manner and appreciate its inner order and beauty.

Introduction

Communicating a difficult concept in a simple manner is an art, and it becomes all the more challenging if these concepts relate to high school mathematics curriculum. The Mathematics Gallery, which opened in the year 2010 at the Birla Industrial & Technological Museum (BITM), responded to this challenge by offering an enjoyable encounter with mathematics through a number of three-dimensional interactive models and hands-on activities. The physicality and interactivity of the gallery encourages young learners to explore and discover the underlying ideas behind some of the abstract formulations they often stumble over in high school mathematics.

Figure 1. Entrance to the Mathematics Gallery at BITM, Kolkata

The entrance to the gallery is adorned with motifs that symbolically link the subject matter and an inspiring quotation from Einstein which says: *"Do not worry about your difficulties in Mathematics; I can assure you that mine are greater".*

Historical Background

The gallery begins with a brief introduction of the history of mathematics. Two scaled down dioramas (Figure 2) have been used to show how ancient people used to count and keep record of their counts in their daily life activities like farming. These are followed by fibre glass plaques depicting the ancient Roman and Hindu-Arabic numeral systems.

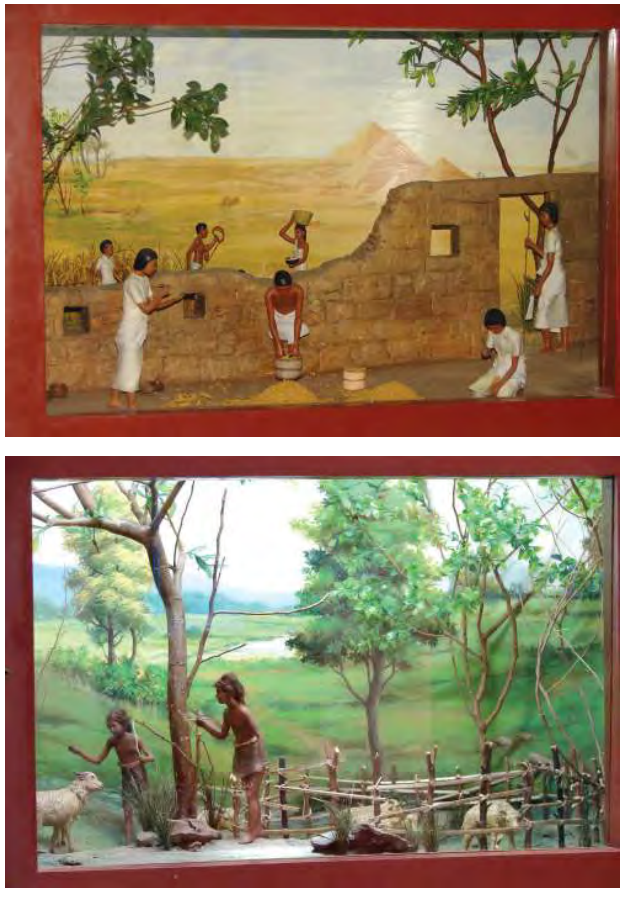


Figure 2. Above two dioramas depict how ancient people used to count and keep record of their counts and measurements.

Pioneering works by ancient mathematicians finds a special place in this section. An innovative multimedia presentation (Figure 3) on the life and works of some of the early pioneers of mathematics allows the visitors to explore and appreciate how mathematical ideas and formulations evolved in different cultures of the world in the early part of its history.

Figure 3. Visitors interact with the exhibit on 'Ancient Mathematicians'

Numbers and Number Systems

Many abstract concepts in mathematics namely, Number System, Series & Progression, Plane and Solid Geometry, Algebra, Functions and Variables, and non-Euclidean Spherical Geometry are elucidated in the gallery with the help of 3-dimensional interactive exhibits which the students can play with and understand the underlying concepts. For example, a Number Line is shown as a vertical line in a mock well in which the surface of water is considered '0' (zero). Any value above this level is positive, while those below are taken as negative numbers. Using an electro-mechanical circuit, a toy frog (used as an indicator) can be made to move along this number line and stop at a number which is the algebraic sum of any two numbers, one positive and one negative. For example, when a visitor inputs +5 and -3, the 'frog' moves and stops above the water surface at + 2 level. But when one inputs +3 and -5, that is, taking away more than what one has, the 'frog' goes below the water surface and stops at the -2 level. When the inputs are +3 and -3, the 'frog' stops at the water surface. This simulated number line thus helps the visitor get the concepts of zero and negative numbers which are otherwise very difficult to appreciate by young learners.

Figure 4. Demonstrating the concept of Number Line physically where a sliding indicator can be programmed to indicate the algebraic sum of 2 numerical input values – one positive and the other negative.

The number systems which we use everyday – the decimal and the binary - are explained in a pair of interactive exhibits (Figures 5 & 6). Through interaction, a visitor understands that Decimal Number System has ten digits, 0 through 9, using which one can form any number, big or small, and that the system uses a base 10.

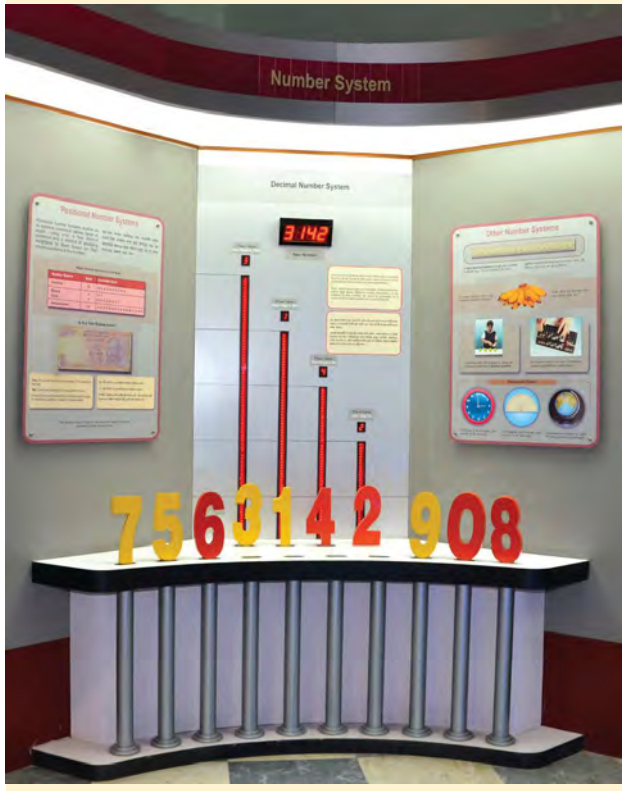


Figure 5a. Exhibit on Decimal Number System and Place Value

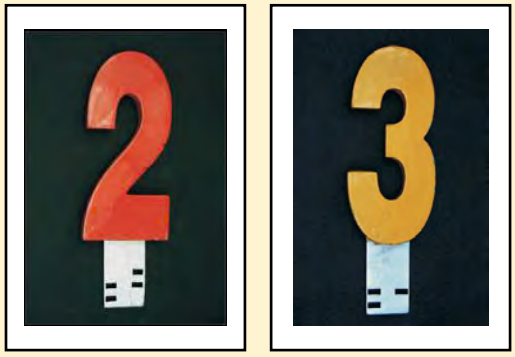


Figure 5b. View of two Digits

In the exhibit, each of the ten numerical symbols or digits carries metal legs (Figure 5b) of the same dimension that allows the user to put any digit in any of the ten slots provided on the table. These metal legs also work as 'codes' that help the electronic sensor fitted inside the slots detect the position of the inserted digits. The display over each slot shows the intrinsic value of the digits wherever they are. But the total value of the number generated by positioning of digits in different slots is given by the big display on top of all. What the users easily understand from playing with the same set of digits is that while their intrinsic values do not change, the value of the number they represent as a sequence changes as they change positions with respect to each other. The idea of place values of digits in the decimal system is thus clearly appreciated by the users.

The binary number system exhibit (Figure 6) works in the same way as the decimal system, except that it contains only two digits, 0 and 1 and each move to the left increases the value by a power of 2. Here also, the visitor can insert any one of the two digits 0 and 1 into the slots to form a binary number and see the equivalent decimal number in the display panel.

*Figure 6. **Exhibit explaining the Binary Number System***

Series and Progression

The concept of Arithmetic and Geometric Progression is presented in a very lucid way. The Arithmetic Progression is shown like a standard staircase with equal height steps such that the railing is a straight line. Geometric Progression on the other hand has unequal steps with heights of each varying in a multiplicative manner bearing a constant ratio. For example, if the height of the first step is 2 units, the next ones are 4 units, 8 units and so on. The railing of such a staircase is therefore curved.

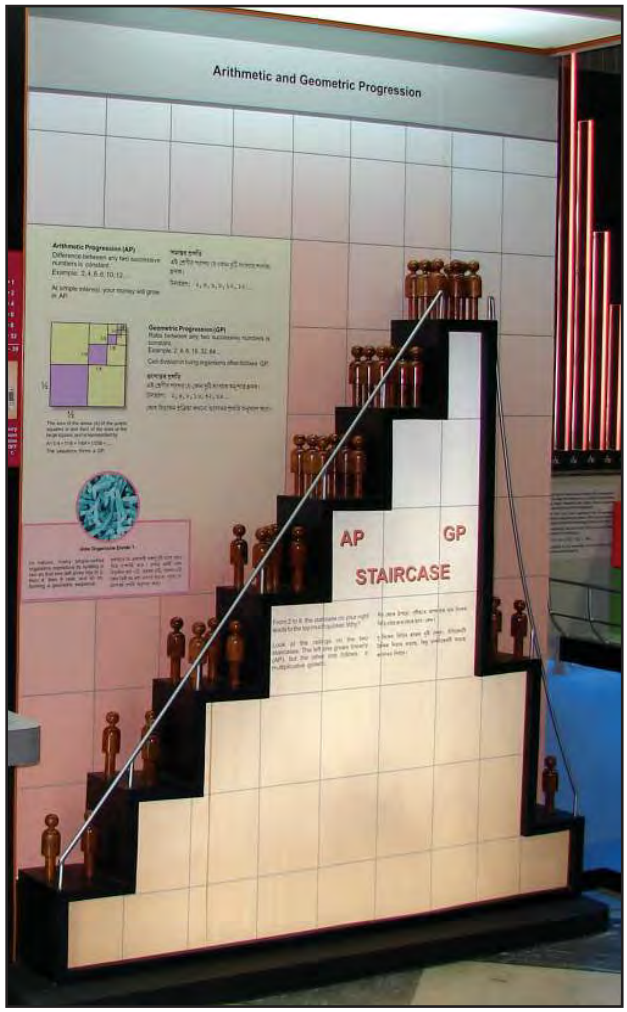
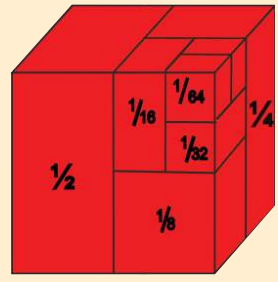


Figure 7. Exhibit on Arithmetic Progression (AP) and Geometric Progression (GP). The growth in AP is uniform and linear, while that in GP is multiplicative and follows a curve as evident from the railings of AP & GP staircases.

What are the values of the series 1+2+4+8+16+32+…. & 1/2+1/4+1/8+1/16+1/32 + …… ? In order to explain a series, we pose this question to a visitor. While one observes that both of them are G. P series, one also finds one special characteristic in them, that is, they are both endless or infinite. The value of the first series mentioned above becomes infinitely large as the value of the term increases and hence it is an example of a divergent series. But the second series is interestingly different. Here, the sum of the series tends to assume a finite value as the series progresses. Hence it is an example of a convergent series.

Figure 8 . The exhibit on 'Divergent and Convergent Series'

This feature of a convergent series is explained in the form of a simple activity.



1/2 + 1/4 + 1/8 + 1/16 + 1/32 +….. = 1

Figure 9. Explaining a Convergent Series

A big wooden cube is divided into a number of parts, namely 1/2 cube, 1/4 cube 1/8 cube, 1/16 cube, 1/32 cube and so on as shown in Figure 9. Assembling all the parts together, one can get the original cube, thus verifying that 1/2+1/4+1/8+1/16+1/32 + …… = 1. It is easy to understand from this activity that a series is a converging one when an infinitely large number of its terms add up to a finite sum. Not only that, once a student gets the concept of infinite converging series, he himself will be able to extend the above observation further, like

$1/3 + 1/3^2 + 1/3^3 + 1/3^4 + 1/3^5 + \ldots\ldots\ldots\ldots = 1/2$

$1/4 + 1/4^2 + 1/4^3 + 1/4^4 + 1/4^5 + \ldots\ldots\ldots\ldots\ldots = 1/3$

…… …… ……

…… …… ……

…… …… ……

$\mathbf{1/n + 1/n^2 + 1/n^3 + 1/n^4 + 1/n^5 + \ldots\ldots\ldots = 1/(n\text{-}1)}$

Concepts in Geometry and Algebra

Simple activities have been designed on algebraic formulae, properties of triangles, polygons and polyhedrons, which help beginners to get an insightful experience. In Algebra, a student can verify the following important algebraic identities through activities by using some wooden and plastic plates and blocks (Figure 10a, 10b & 10c) :

(1) $(a+b)^2 = a^2 + 2ab + b^2$

(2) $(a-b)^2 = a^2 - 2ab + b^2$

(3) $a^2 - b^2 = (a+b)(a-b)$

(4) $(a+b)^3 = a^3 + 3ab^2 + 3a^2b + b^3$

Figure 10a . Verifying the standard Algebraic Identities

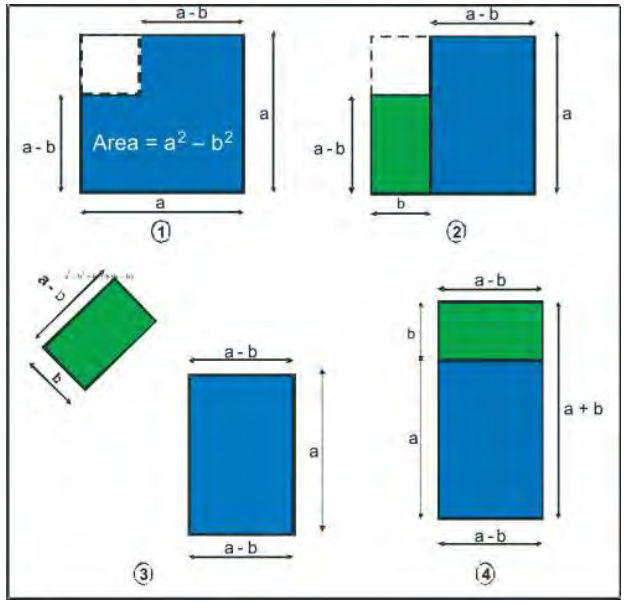


Figure 10b . Showing $a^2 - b^2 = (a+b)(a-b)$

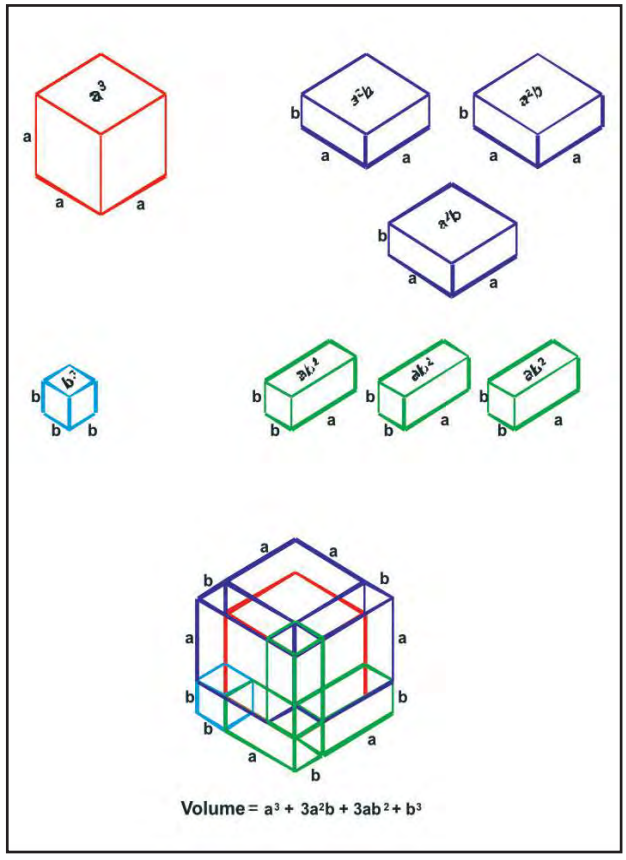


Figure 10c . Showing $(a+b)^3 = a^3 + 3ab^2 + 3a^2b + b^3$

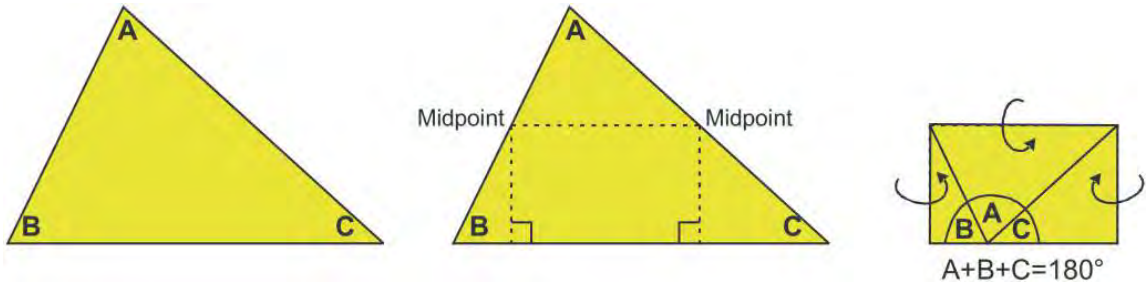


Figure 11a . Showing sum of the angles of a plane triangle = 180°

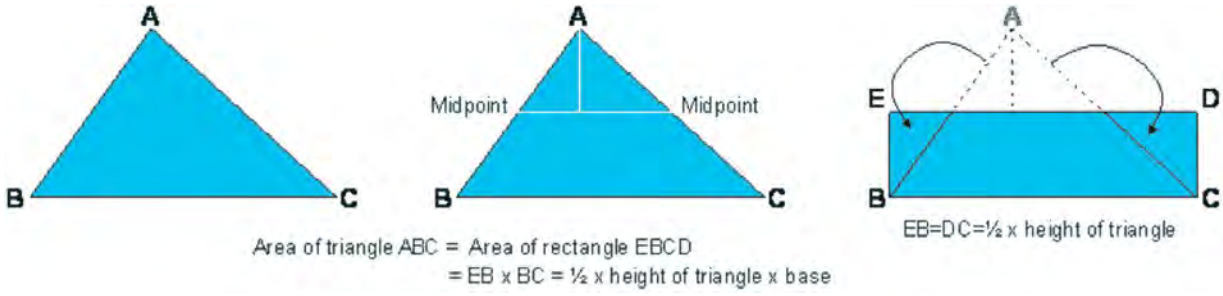


Figure 11b . Finding the area of a Plane Triangle

Similarly in Geometry, in the exhibit 'Plane Geometry' (Figure 11c), by folding or arranging parts of triangular laminar sheets in definite manners as shown in Figures 11a and 11b, a visitor can physically prove that the sum of the angles of a triangle is 180° or the area of a triangle is ½ x (base) x (height). Continuing the experiments with triangles, one can easily find out the sum of the angles or the area of any plane polygon, because a polygon is actually composed of a number of triangles.

'Platonic Solids' or Polyhedrons of Plato is another challenging concept of Solid Geometry. The exhibit provides the students with scopes for experimentation that help them grasp the idea of these unique solid figures. The polygonal faces of all the Plato's polyhedrons are placed on a table in form of wooden plates. These plates have the shapes of regular triangle, square and regular pentagon. The students are given the challenge to rearrange these plates (Figure 12a & 12b) in definite manners and build the polyhedrons.

Figure 11c . Learning the properties of basic Geometrical Figures

Figure 12a . Students experimenting with the Platonic Solid exhibit

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Figure 12b . Students interacting with the Platonic Solid exhibit

This activity makes them understand the unique features of Plato's polyhedrons, like (i) Polygonal faces are all regular, for instance, *equilateral triangles* for Tetrahedron, Octahedron and Icosahedron, *squares* for Hexahedron or Cube and *regular pentagons* for Dodecahedron (ii) polygonal faces are all equal (iii) face-to-face angles are equal (iv) edge-to-face angles are equal, and (v) there are only 5 such polyhedrons possible, namely, *Tetrahedron, Octahedron, Hexahedron (or Cube), Dodecahedron and Icosahedron.*

Students visiting the Mathematics Gallery often get to know something more than what their curriculum exposes them to. For example, Pythagoras Theorem is known to them as *"The square on the hypotenuse of a right angled triangle is the sum of the squares on the other two sides"*. However, on interacting with 'Pythagoras Theorem' exhibit in the gallery, they come to know that the theorem is true not only for the squares, but also for any similar figures drawn on the sides of the right angled triangle. In the exhibit (Figure 13), very thin square shaped chambers are made on the three sides of a right angled triangle. A certain volume of a liquid that fills the chamber on the hypotenuse is also found to completely fill the square shaped chambers on the other two sides of the triangle, thus proving the theorem.

Figure 13 . Exhibit showing Pythagoras Theorem

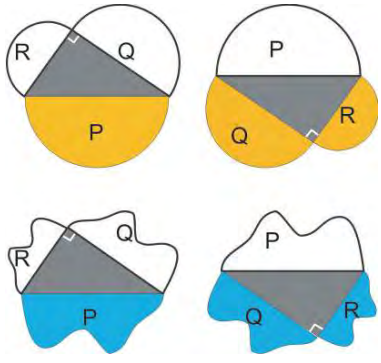

Figure 13a . Pythagoras Theorem with semi-circular and similar shaped compartments. Here, P = Q + R

Here, one can verify that the Pythagoras Theorem holds good also for semi-circular and similar shaped chambers that are built on three sides of a right angled triangle (Figure 13a).

Spherical Geometry

A visitor gets an idea of non-Euclidean spherical geometry when he or she observes the difference between a plane triangle and a spherical triangle. In the exhibit (Figure 14 & 14a), one can see that any three non-collinear points on the earth surface form a Spherical Triangle, and unlike a plane triangle, the sides of a spherical triangle are curved and its internal angles add up to more than 180°. The exhibit also shows that three places on the earth surface, although in the same line, are found to lie on a curved line in the map developed on plain paper. This is because non-Euclidean spherical geometry, and not plane Euclidean geometry, applies on the curved earth surface. This fact further makes him understand and appreciate why the air travel paths in Air-route maps are curved.

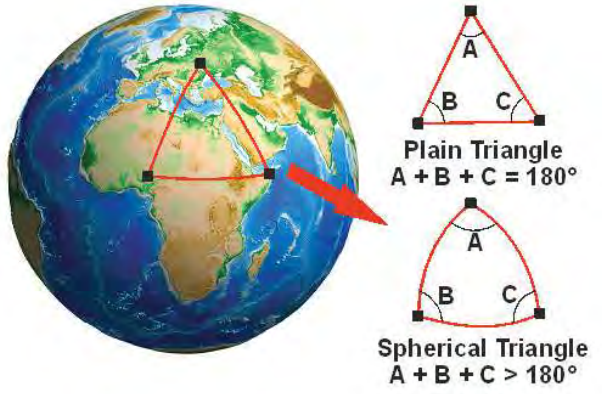

Figure 14. Plain Triangle and Spherical Triangle

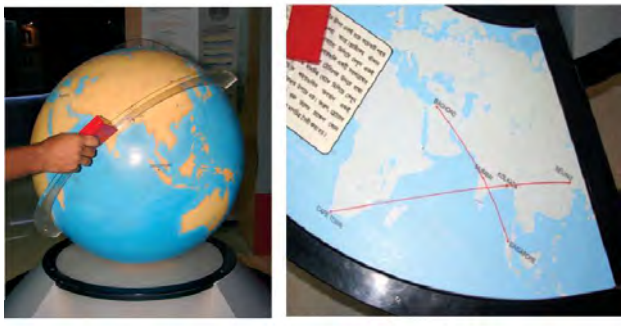

Figure 14a . Elucidating why the air travel paths in air-route maps are curved

Mathematical Function

The exhibit on 'Functions' in the gallery (Fig.15b) is an attempt to elucidate the concept of mathematical functions in physical terms. The exhibit explains what a linear and a quadratic (non-linear) function physically imply. Three containers of different shapes as shown in Fig. 15a are filled by means of equally rated pumps so as to ensure that the volume of water entering each container per unit time are equal. The objective is to study the rise of water levels in these containers with time. To achieve this, special electronic tapes (pressure dependant e-tapes) have been used to sense the water levels and subsequently feed these values to a computer, which outputs the results (water level vs. time) on the monitors placed above the respective containers (Fig. 15a). Water level in the container with uniform cross-section evidently shows a linear relationship with time, while water levels for the other containers exhibit parabolic relationship with time.

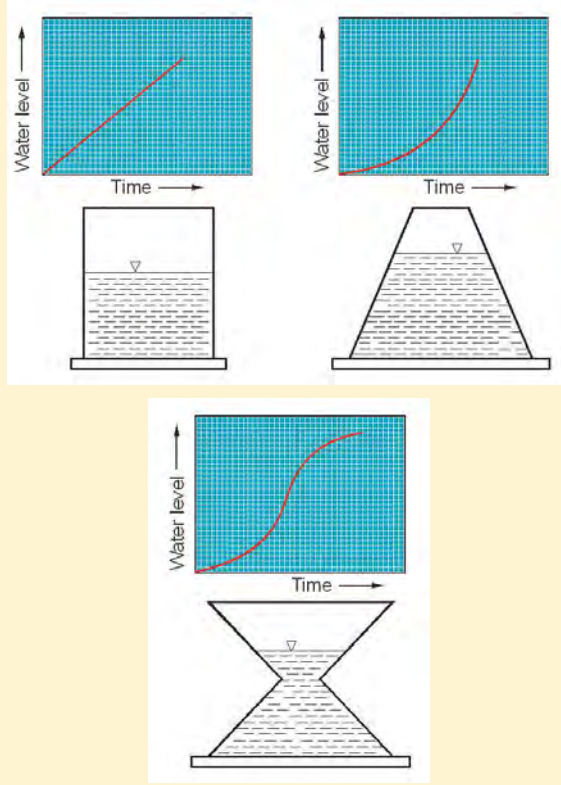

Figure 15a . Real time plot of Water Level vs. Time, while uniform flow of water fills three different containers

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Figure 15b. Showing water level as different functions of time while uniform flow of water fills up containers of uniform and non-uniform cross-section. Here, functions are linear and quadratic.

Law of Average

The exhibit titled 'Law of Average' introduces the concept and usefulness of statistical techniques through a simple measurement activity. A visitor stretches his or her forearm fully on a flat bed lined with a number of switches and presses the furthest switch he or she can reach. This in fact measures the length of their forearms (a cubit) which is statistically found to bear a relationship with the individual's height. The pressing of the switch lights up a vertical row of LEDs to corresponding heights, thus converting the length of the user's forearm to his or her height. One finds that on an average, our heights are roughly equal to 3.8 to 4 times the cubit length.

Concepts of Calculus: Differentiation & Integration

Calculus as a mathematical tool is difficult to grasp by young learners. There are a few exhibits in the gallery that were designed to illustrate the basic concepts of calculus like limit, differentiation and integration etc. in a simple manner. *Differentiation* is a rate measurement process and *Integration* means a summation process – these ideas are made quite clear to the students by two exhibits in the gallery (Figures 16b & 16c).

A stick is made to move such that its mid-point slides in a curved slot (Figure 16a). Its slope or gradient changes as indicated by the angle ? it makes with x-axis. The rate at which ordinate (y-coordinate) of a point in the curve $y = f(x)$ changes with respect to its abscissa (x-coordinate) is determined by dy/dx or tan? at that point, and is represented by a tangent drawn to the curve at that point. The stick physically takes the position of the tangent, and hence as the stick moves in x-y plane along $y = f(x)$, the slope of the stick or dy/dx changes. Thus, the stick moving along the curved slot is the visual and physical representation of dy/dx or differentiation of $y = f(x)$.

Once differentiation shows us how to measure the rate at which a variable quantity changes with respect to another, the concept is applied in computing the exact

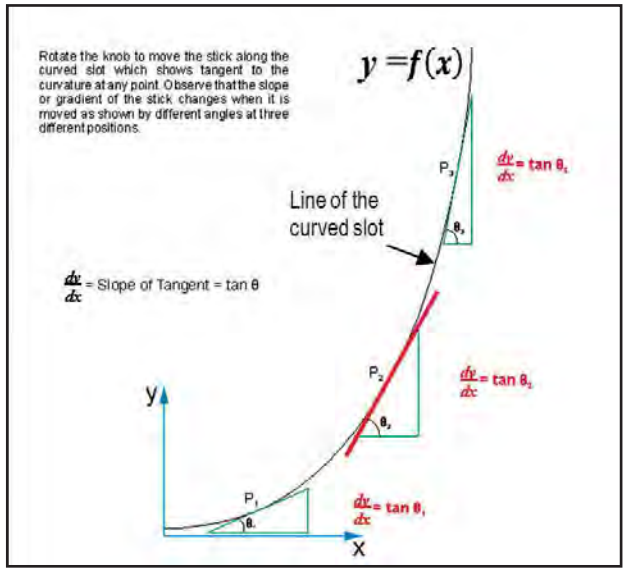


Figure 16a . Explaining the concept of Differentiation

length of a curved line or exact area of a curved surface shown in Figure 16b, which is otherwise not possible using standard geometrical methods. The surface area of the inverted funnel (Figure 16b) could be very approximately calculated by adding up the peripheral areas of the circular plates the funnel is made up of. However, differentiation technique allows us to calculate the rate of change of height with change in its radius, and hence the curved surface area can be perfectly computed using the technique of integration.

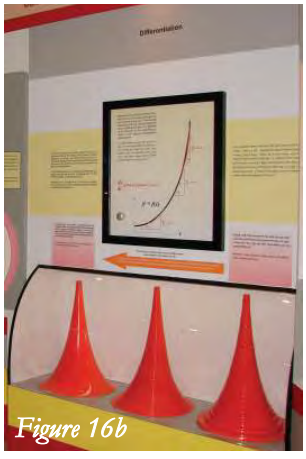


Figure 16b

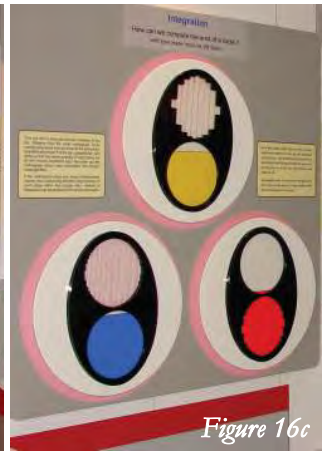


Figure 16c

Figure 16b. *Using differentiation for determining the profile of Curved Surface*
Figure 16c. *Exhibiting the concept of Integration*

The exhibit on 'Integration' presents the concept in a comprehensible form (Figure 16c). On three circular discs that can be rotated in a vertical plane, two equal circular compartments are made and interconnected (Figure 16d). One of these compartments in each has a number of rectangular areas forming the circular shape, while the other is perfectly circular. Rectangular areas in disc 2 are narrower and more in number than in disc 1 and in disc 3, these are much narrower.

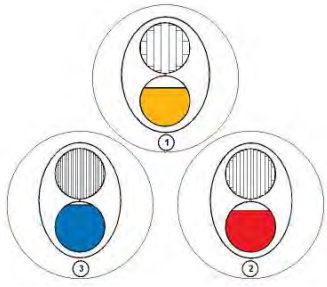


Figure 16d. Finding the Area of a Circle

On turning the three discs upside down to allow the coloured liquid from the chambers having rectangular peripheral walls to trickle down to the circular chambers, it is observed that the liquid does not fill the circular compartments completely. Narrower is the size of rectangular area that make up the inner periphery of the upper chambers, smaller is the unfilled space in the circular compartments and vice versa. This clearly shows that if there were infinitely large numbers of rectangular areas with infinitesimally narrow width, then in the limit, this width tends to zero leaving no unfilled space in the circular compartment, thus enabling us to compute the exact area of the circle.

Maxima – Minima : Application of Differentiation

Proper realization of the physical significance of Differentiation and Integration sensitizes students to explore how Calculus is applied to solve physical problems. The exhibit on 'Maxima – Minima' addresses the students on this issue. A challenge is given to them to find out which of the three shapes of the containers of equal volume (Figure 17a) has the minimum surface area ?

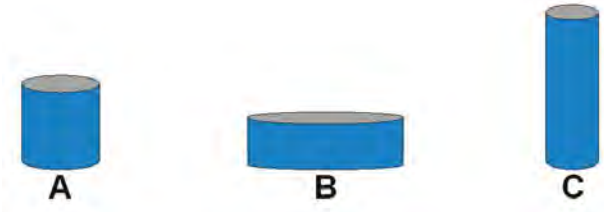


Figure 17a . Three containers of equal volume. Which shape has the minimum surface area ?

Sometimes solving such problems becomes very important. For example, soft drink cans are manufactured in huge numbers and the manufacturer would like to save on material used for making the cans. Differentiation can help one find out the exact solution instead of going into cumbersome trials and errors. The relation between the surface area and the radius of the cylindrical container shows that the container's surface area is minimum when differentiation of its surface area (S) with respect to its radius (r), i.e. dS/dr is zero (Figure 17b). This is possible only when the height of the container is equal to twice the radius (or diameter) of the container.

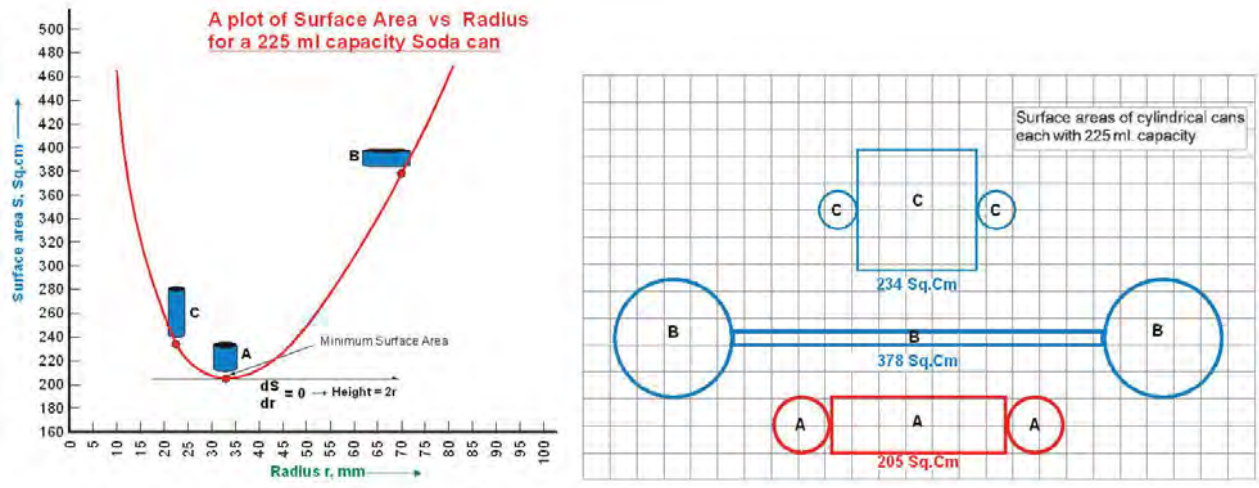


Figure 17b. Calculating the minimum surface area of a cylindrical container having equal volume but different shapes. Surface area (S) is a function of Radius (r), S = f(r)

Students can verify this by taking a container and comparing its surface area with those drawn on the table. They can observe that the container with height equal to its diameter has the minimum surface area.

Mathematical Activities

The activity hall of Mathematics Gallery is about mathematical challenges and brain teasers. Puzzles, mazes, juggling with shapes and figures keep visitors busy and engrossed for hours.

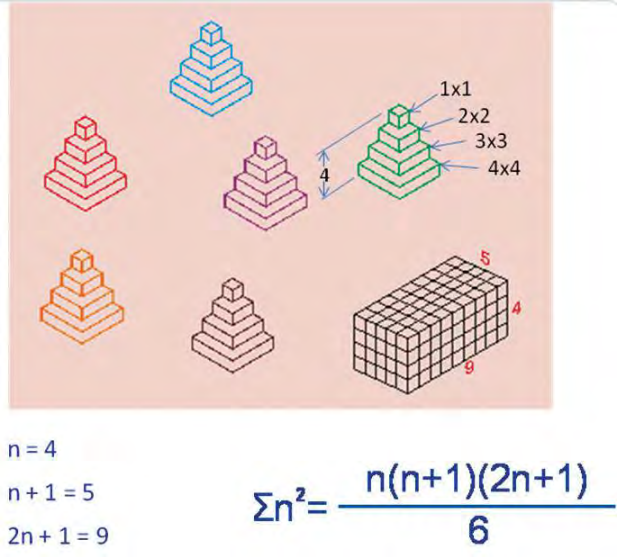


Figure 18a. A 3D model to find out the sum of squares of natural numbers

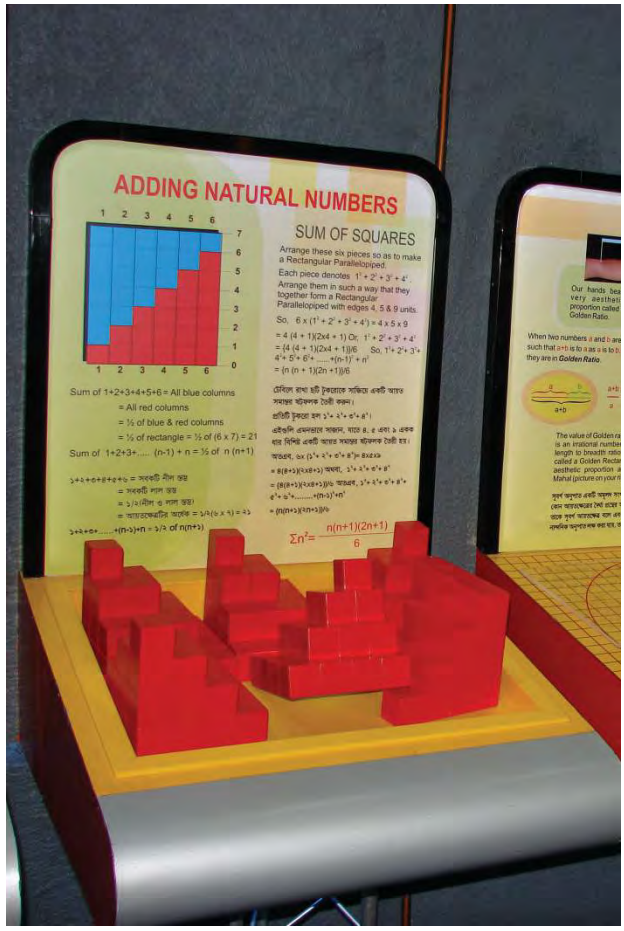


Figure 18b. Another 3D model to find out the sum of squares of natural numbers

There are also other activities in this section that provide opportunities to carry out experiments on a few important mathematical rules and formulae. For example, an experimental model has been designed that would enable a student to find out the sum of the squares of natural numbers, i.e. $1^2 + 2^2 + 3^2 + 4^2 + 5^2 + ... + n^2$. Six identically stepped blocks, each with four square shaped steps, are provided for this activity. The steps of each block denote 1^2, 2^2, 3^2 and 4^2 according to their sizes, like 1x1x1, 2x2x1, 3x3x1 and 4x4x1 cubic units (Figure 18a & 18b). One has to arrange and combine all the six blocks in such a way that the resultant block is a rectangular parallelepiped, whose edges are 4, 5 and 9 units as shown in the figure. The volume of the rectangular parallelepiped is 4x5x9 cubic units.

We can say that for 4 steps in the block

$$6 \times (1^2 + 2^2 + 3^2 + 4^2) \times 1 = 4 \times 5 \times 9 = 4 \times (4+1) \times (2 \times 4 + 1)$$

$$\rightarrow (1^2 + 2^2 + 3^2 + 4^2) = 1/6 \{4 \times (4+1) \times (2 \times 4 + 1)\}$$

So, for 5 steps in the block $\rightarrow (1^2 + 2^2 + 3^2 + 4^2 + 5^2)$
$= 1/6 \{5 \times (5+1) \times (2 \times 5 + 1)\}$

for 6 steps in the block $\rightarrow (1^2 + 2^2 + 3^2 + 4^2 + 5^2 + 6^2)$
$= 1/6 \{6 \times (6+1) \times (2 \times 6 + 1)\}$

....
....

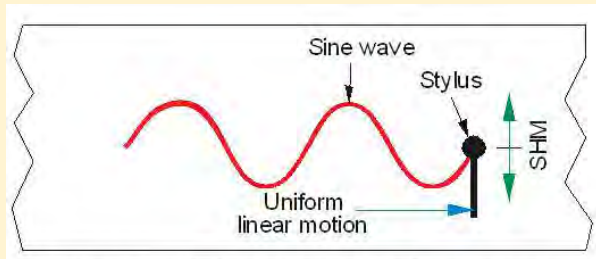
For n steps in the block $\rightarrow$ **$(1^2 + 2^2 + 3^2 + ... + n^2)$**

$= 1/6 \{n (n+1) (2n+1)\}$

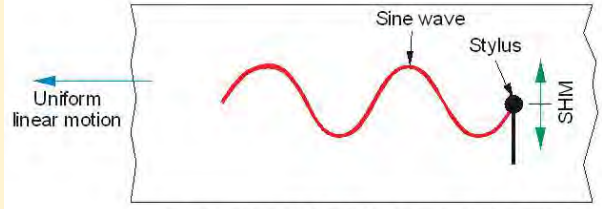
Apart from applying the standard method of summation of series in school or college, he can thus get to know the physical interpretation of the summation process by doing this experiment.

Another activity most students love to do is generating a Sine wave or a Sinusoidal curve. They normally apply analytical methods in drawing mathematical curves in their school/college curriculum. The basic idea of the activity is to trace a Sine wave using mechanical means by compounding a Simple Harmonic Motion (SHM) and a uniform linear motion in mutually perpendicular directions (Figure 19). A student generally finds problem in generating the SHM. A mechanism has been devised to facilitate him to do the activity in the gallery.

When a particle moves in a circular path uniformly, the foot of the perpendicular dropped from it on a diameter of the circle executes an SHM along the diameter – this fact is known to him and the mechanism referred above exactly does this job. He rotates the round plate with the knob to generate a reciprocating motion of the stylus (Figure 19a). Since it is practically not possible to rotate the plate with perfectly uniform



Stylus is given both SHM and uniform linear motion in mutually perpendicular directions.



Stylus is given SHM and the paper is given opposite uniform linear motion in mutually perpendicular directions.

Figure 19

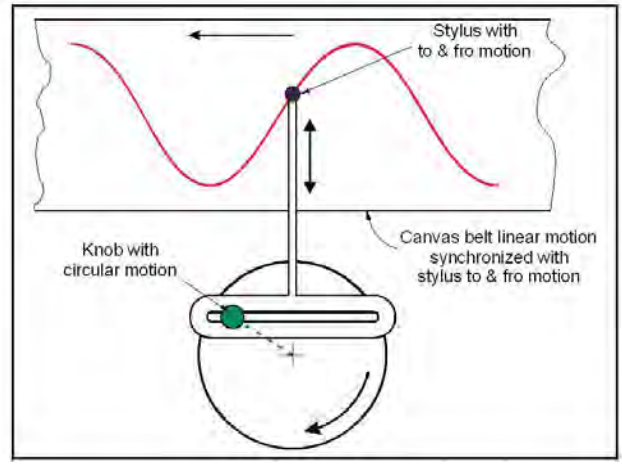


Figure 19a. Mechanism converting Circular Motion into a Reciprocating Motion

motion, the output reciprocating motion of the stylus will not be an SHM. In order to overcome this problem, the circular motion of the plate is mechanically linked with the linear motion of the canvas belt on which the Sine wave is to be drawn. This design ensures synchronization of the reciprocating motion of the stylus with the linear motion of the canvas belt, so that Sinusoidal wave will be traced on the canvas by the stylus whenever there is an input circular motion, no matter whether it is uniform or not (Figure 19b).

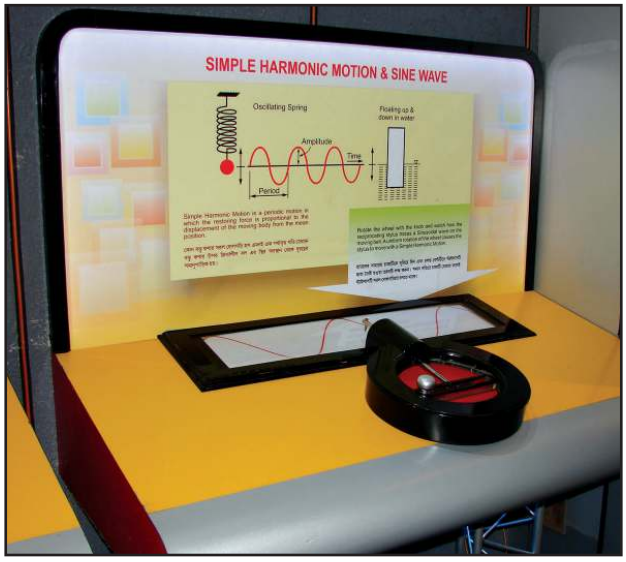


Figure 19b. An interactive exhibit to convert circular motion into a Simple Harmonic Motion and trace a Sine Wave

In the Activity Area, a student can find out various mathematical shapes in nature in the gallery itself. He also enjoys discovering some numerical orders and patterns in nature - in human body, leaf, floral petal arrangement, building architecture, banking and finance and the like. *Golden Ratio* is an appropriate example of nature's mathematical beauty that renders the most beautiful, aesthetic and compact form and shape to the objects in nature. Here one can create a beautiful spiral applying Golden Ratio. This makes one comprehend and appreciate the beauty of mathematics as it helps us find the hidden patterns in the things and events happening in the natural and manmade worlds.

Live Math Demo Corner cum Classroom

But the highlight of the gallery is its 'Live Math Demo Corner cum Classroom' (Figure 20), an area inside the gallery that is fitted with a digital smart board for conducting math demos, especially on Vedic mathematics, and on curricular mathematics. School students accompanied by their mathematics teachers are using this facility round the year. Live demos are conducted by BITM educators on Vedic mathematics regularly for the visiting school children. The advantage for the schools for taking their math classes here is that the teacher can always go back to the respective exhibit in the gallery for experimenting and verifying the key ideas being taught.

Figure 20. Math Demo Corner cum Classroom

Concluding remarks

Ever since its opening in 2010, the Mathematics Gallery has evoked positive responses from visitors, especially from school students and their mathematics teachers. Some schools in Kolkata are using the gallery as their extended practical classroom as they visit the Mathematics Gallery on regular basis and conduct activity sessions by students, organize math workshops and practical demonstrations. The gallery has also generated serious interest among many schools and colleges for setting up mathematics laboratories in their own institutions, for which they are approaching BITM for help and support. For example, BITM has helped set up a Mathematics laboratory in Institute of Education for Women at Hastings, Kolkata and Raja N. L. Khan Girls' College in Medinipur, West Bengal.

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Science in the Baburnama : A Critical Study

Indranil Sanyal

Introduction

The *Baburnama* (Memoirs of Babur) is the work of Zahiruddin Muhammad Babur (1483-1530), the founder of Mughal dynasty in India. Written in the form of a diary, Babur's memoirs are the first true autobiography in Islamic literature, and also of the medieval India. The *Baburnama* is one of the marvels of the medieval world. "It belongs to a handful of the world's literary works that can accurately be described as unique"(Amitav Ghosh).

Written originally in Chagatai Turkic, a now extinct dialect of erstwhile Soviet Central Asia and the adjacent region of Chinese Turkestan or Xinjiang, and a language of Ural-Altaic group, Babur's style of writing was highly Persianized. The Memoires was later translated into Persian and illustrated during the reign of Babur's grandson Emperor Akbar.

As a writer and intellectual, Babur stood much above the men of his time. The Baburnama offers observations of a highly educated Central Asian Royal of the Medieval Era of the world he had seen. There is much on the war and politics of his time but also extensive descriptions on the physical geography, the flora and fauna, the environment, the villages and towns, the people and human relationships.

Despite his preoccupation with war and administration, Babur had an inquisitive mind with fantastic scientific insight and scientific temper. The Baburnama described with minute details and critical observations the Physical Geography, Flora & Fauna, Weights & Measures and Time Reckoning System of 'Hindustan' which remained unparalleled till the 19th century.

Babur's Description of Hindustan

Babur described Hindustan in the Section III of the Memoirs and first made entries during AH 932 (October 18, 1925- October 08, 1926) which is of course the time of Babur's fifth and final expedition to India. Babur started his descriptions of Hindustan with this paragraph which shows his accurate knowledge of the geography of India:

The country of Hindustan is extensive, full of men, and full of produce. On the east, south, and even on the west, it ends at its great enclosing ocean (muhit darya-st-gha). On the north it has mountains which connect with those of Hindu-Kush, Kafiristan and Kashmir. North-west of it lie Kabul, Ghazni and Qandahar. Dihli is held to be the capital of the whole of Hindustan.

Babur then moves on to describe the climate and people of India

Hindustan is of the first climate, the second climate, and the third climate; of the fourth climate it has none. It is a wonderful country. Compared with our countries it is a different world; its mountains, rivers, jungles and deserts, its towns, its cultivated lands, its animals and plants, its peoples and their tongues, its rains, and its winds, are all different. In some respects the hot-country (garm-sit) that depends on Kabul, is like Hindustan, but in others, it is different. Once the water of Sind is crossed, everything is in the Hindustan way (tariq): land, water, tree, rock, people and horde, opinion and custom.

After crossing the Sind-river (eastwards), there are countries, in the northern mountains mentioned above, appertaining to Kashmir and once included in it, although most of them, as for example, Pakll and Shahmang (?), do not now obey it. Beyond Kashmir there are countless peoples and hordes, parganas and cultivated lands, in the mountains. As far as Bengal, as far indeed as the shore of the great ocean, the peoples are without break. About this procession of men, one has been able to give authentic information in reply to our enquiries and investigations. So far people have been saying that they call these hill-men Kas. It has struck me that as a Hindustani pronounces shin as sin (i.e. sh as s\ and as Kashmir is the one respectable town in these mountains, no other indeed being heard of, Hindustanis might pronounce it Kasmlr. These people trade in musk-bags, saffron, lead and copper.

One should then be surprised to read Babur's authentic descriptions (much like a good teacher of Geography) of the mountain ranges and rivers of India.

Hindus call these mountains Sawalak-parbat. In the Hindi tongue Sawai-lak means one lak and a quarter, that is, 125,000, and Parbat means a hill, which makes 125,000 hills. The snow on these mountains never lessens; it is seen white from many districts of Hind, as, for example, Lahor, Sihrind and Sambal. The range, which in Kabul is known as Hindu-kush, comes from Kabul eastwards into Hindustan, with slight inclination to the south. The Hindustanat are to the south of it. Tibet lies to the north of it and of that unknown horde called Kas.

Many rivers rise in these mountains and flow through Hindustan. Six rise north of Sihrind, namely Sind, Bahat (Jilam),Chanab, Rawi, Blah, and Sutluj; all meet near Multan, flow westwards under the name of Sind, pass through the Tatta country and fall into the 'Uman(-sea). Besides these six there are others, such as Jun (Jumna), Gang (Ganges), Rahap (Rapti?), GumtI, Gagar (Ghaggar), Siru, Gandak and many more ; all unite with the Gang-darya, flow east under its name, pass through the Bengal country, and are poured into the great ocean. They all rise in the Sawalak-parbat. Many rivers rise in the Hindustan hills, as, for instance, Chambal, Banas, Bitwa, and Sun (Son). There is no snow whatever on these mountains. Their waters also join the Gang-darya.

Another Hindustan range runs north and south. It begins in the Dihll country at a small rocky hill on which is Firuz Shah'sresidence, called Jahan-nama, and, going on from there, appears near Dihll in detached, very low, scattered here and there, rocky little hills. Beyond Miwar, it enters the Biana country. The hills of Sikri, Bar and Dulpur are also part of this same including tuta range. The hills of Guallar they write it Galwr although they do not connect with it, are off-sets of this range; so are the hills of Rantanbur, Chitur, Chandiri, and Mandau. They are cut off from it in some places by / to 8 kurohs (14 to 16 m). These hills are very low, rough, rocky and jungly. No snow whatever falls on them. They are the makers, in Hindustan, of several rivers.

Next, Babur describes the irrigation and agriculture of India :

The greater part of the Hindustan country is situated on level land. Many though its towns and cultivated lands are, it nowhere has running waters. Rivers and, in some places, standing- waters are its "running- waters". Even where, as for some towns, it is practicable to convey water by digging channels, this is not done. For not doing it there may be several reasons, one being that water is not at all a necessity in cultivating crops and orchards. Autumn crops grow by the downpour of the rains themselves; and strange it is that spring crops grow even when no rain falls. To young trees water is made to flow by means of buckets or a wheel. They are given water constantly during two or three years; after which they need no more. Some vegetables are watered constantly. In Lahor, Dibalpur and those parts, people water by means of a wheel. They make two circles of ropes long enough to suit the depth of the 'well, fix strips of wood between them, and on these fasten pitchers. The ropes with the wood and attached pitchers are put over the well-wheel. At one end of the wheel-axle a second wheel is fixed, and close to it another on an upright axle. This last wheel the bullock turns; its teeth catch in the teeth of the second, and thus the wheel with the pitchers is turned. A 'trough is set where the water empties from the pitchers and from this the water is conveyed everywhere.

In Agra, Chandwar, Biana and those parts, again, people water with a bucket; this is a laborious and filthy way. At the well-edge they set up a fork of wood, having a roller adjusted between the forks, tie a rope to a large bucket, put the rope over the roller, and tie its other end to the bullock. One person must drive the bullock, another empty the bucket. Every time the bullock turns after having drawn the bucket out of the well, that rope lies on the bullock-track, in pollution of urine and dung, before it descends again into the well. To some crops needing water, men and women carry it by repeated efforts in pitchers.

Animals and Birds of Hindustan

The most absorbing part of Baburnama is its descriptions (with critical analysis) of the flora and fauna of India. Babur starts with a description of Elephant, the animal which fascinated him the most :

The elephant, which Hindustanis call Hati, is one of the wild animals peculiar to Hindustan. It inhabits the (western?) borders of the Kalpi country, and becomes more numerous in its wild state the further east one goes (in Kalpi?). From this tract it is that captured elephants are brought in Karrah. The elephant is an immense animal and very sagacious. If people speak to it, it understands; if they command anything from it, it does it. Its value is according to its size; it is sold by measure; the larger it is, the higher its price. People protracted beyond the time for which they have provided food, a large portion necessarily dies of hunger. Therumour that it is heard of in some islands as 10 qari high, but in this tract it is not seen above 4 or 5. It eats and drinks entirely with its trunk; if it loses the trunk, it cannot live. It has two great teeth (tusks) in its upper jaw, one on each side of its trunk; by setting these against walls and trees, it brings them down; with these it fights and does whatever hard tasks fall to it. People call these ivory; they are highly valued by Hindustanis. The elephant has no hair.It is much relied on by Hindustanis, accompanying every troop of their armies. It has some useful qualities: it crosses

great rivers with ease, carrying a mass of baggage, and three or four have gone dragging without trouble the cart of the mortar it takes four or five hundred men to haul.But its stomach is large; one elephant eats the corn of two strings of camels.

Among other animals, Babur described not only in detail but with scientific accuracy Rhinoceros, Wild Buffalo, different varieties of deer, nilgai, antelope, monkeys, squirrel etc. typical to India. Let us consider Babur's comparison of the anatomy of rhinoceros and horses :

The rhinoceros is another. This also is a large animal, equal in bulk to perhaps three buffaloes. The opinion current in those countries (Transoxonia) that it can lift an elephant on its horn, seems mistaken. It has a single horn on its nose, more than nine inches (qartsh) long; one of two qartsh is not seen. Out of one large horn were made a drinking-vessel and a dice-box, leaving over [the thickness of] 3 or 4 hands. The rhinoceros hide is very thick; an arrow shot from a stiff bow, drawn with full strength right up to the arm-pit, if it pierce at all, might penetrate 4 inches (atitk, hands). From the sides of its fore and hind legs, folds hang which from a distance look like housings thrown over it. It resembles the horse more than it does any other animal. As the horse has a small stomach (appetite?), so has the rhinoceros; as in the horse a piece of bone (pastern?) grows in place of small bones (knuckles), so one grows in the rhinoceros ; as in the horse's hand there is kumuk (or gumuk, a tibia or marrow), so there is in the rhinoceros.

The anatomical details by which Babur supports this statement are difficult to understand, but his grouping of the two animals is in agreement with the modern classification of them as two of the three Ungulata vera, the third being the tapir. Babur has also explored the linguistic origin of names of different animals he saw in India. Take for example of deer :

Another is a deer (kiytti) after the fashion of the male deer (airkakt huna) ….. Its back is black, its belly white, its horns longer than the hunds but more crooked. A Hindustani calls it kalahara, a word which may have been originally kala -haran or black-buck, and which has been softened in pronunciation to kalahara.

One would be astonished at Babur's minute description of the flora and fauna of India. This shows his ability to observe nature keenly and to critically analyse it. For example, let us go through the description of Peacock :

The peacock is one. It is a beautifully coloured and splendid animal. Its form is not equal to its colouring and beauty. Its body may be as large as the crane's (turna) but it is not so tall. On the head of both cock and hen are 20 to 30 feathers rising some 2 or 3 inches high. The hen has neither colour nor beauty. The head of the cock has an iridescent collar (tauq susant); its neck is of a beautiful blue; below the neck, its back is painted in yellow, parrot-green, blue and violet colours. The flowers on its back are much the smaller; below the back as far as the tail-tips are [larger] flowers painted in the same colours. The tail of some peacocks grows to the length of a man's extended arms. It has a small tail under its flowered feathers, like the tail of other birds; this ordinary tail and its primaries are red. It is in Bajaur and Sawad and below them; it is not in Kunur and the Lamghanat or any place above them. Its flight is feebler than the pheasant's (girghawal); it cannot do more than make one or two short flights. On account of its feeble flight, it frequents the Hills or jungles, which is curious, since jackals abound in the jungles it frequents. What damage might these jackals not do to birds that trail from jungle to jungle, tails as long as a man's stretch (qulach}! Hindustanis call the peacock mor. Its flesh is lawful food, according to the doctrine of Imam Abu Hamfa ; it is like that of the partridge and not unsavoury, but is eaten with instinctive aversion, in the way camel-flesh is.

In India, Babur came across with many anecdotes about animals and birds. But like a man with true scientific temper, he did not accept them on face value. Take for example of a talking Parrot :

It is an excellent learner of words. We used to think that whatever a Parrot or a Sharak (Himalayan Sterling or Myna) might say of words people had taught it, it could not speak of any matter out of its own head. At this juncture one of my immediate servants Abu'l-qasim Jalazr, reported a singular thing to me. A parrot of this sort whose cage must have been covered up, said, "Uncover my face; I am stifling." And another time when palki bearers sat down to take breath, this parrot, presumably on hearing wayfarers pass by, said, "Men are going past, are you not going on?" Let credit rest with the narrator, but nevertheless, so long as a person has not heard with his own ears, he may not believe!

Wherever Babur led an expedition, he looked for new flora and fauna. Whenever he came across a new one, he tried to find out its origin and characteristics. Here are some examples :

The Sharak (Persian) is another. It is numerous in the Lamghanat and abounds lower down, all over Hindustan. Like

the parrot, it is of many kinds. The kind that is numerous in the Lamghanat has a black head; its primaries (qana) are spotted, its body rather larger and thicker than that of the chughurchuq (Turkic). People teach it to speak words. Another kind they call pinaazvali; they bring it from Bengal; it is black all over and of much greater bulk than the Sharak (here, house Myna). Its bill and foot are yellow and on each ear are yellow wattles which hang down and have a bad appearance. It learns to speak well and clearly. Another kind of Sharak is slenderer than the last and is red round the eyes. It does' not learn to speak. ……. Again, at the time when (934 A H.) I had made a bridge over Gang (Ganges), crossed it, and put my adversaries to flight, a kind of Sharak was seen, in the neighbourhood of Laknau and Aud, for the first time, which had a white breast, piebald head, and black back. This kind does not learn to speak.

Babur has described large number of birds in his memoires. They include Peacock, Parrot, Sharak (Myna and some other birds), Lujeh, Partridge (Durraj), Pulpaikar, Chilsi, Sham, Budineh or Quail, Kharchal (or Bustard), Charz (or Floriken), Baghri-kara (or Rock-Pigeon), Water-fowl, Dig (or Adjutant), Saras, Minkisa, Yak Ding, Buzek (or Curlew), Gheret-pai, Shahmurgh, Zumej, Starling, Ala-kurgheh (or Magpie), Crow-pheasant, Chamgidri (or Flying Fox), Aakeh, Karcheh or Koel. It is surprising to note that Babur has included Flying Fox in the list of birds!

Among the aquatic animals, Babur's description of crocodiles is interesting. He described three types: *shlr-tibi, Siyah-sar*, and Gharial. Here are some examples.

The (P.) Siyah-sar (black-head) is another. This also is like a lizard. It is in all rivers of Hindustan. One that was taken and brought in was about 4-5 qari (cir. 13 feet) long and as thick perhaps as a sheep. It is said to grow still larger. Its snout is over half a yard long. It has rows of small teeth in its upper and lower jaws. It comes out of the water and sinks into the mud……

The Gharial (Gavialus gangeticus} is another. It is said to grow large; many in the army saw it in the Saru (Gogra) river. It is said to take people; while we were on that river's hanks (934-935 A.H.), it took one or two slave- women, and it took three or four camp-followers between Ghazipur and Banaras. In that neighbourhood I saw one but from a distance only and not quite clearly……

Babur named many animals and birds in Chagatai Turkic, which became difficult to understand later on. The problem was partially solved by Babur's Grandson Akbar and Great Grandson Jahangir, who himself was a naturalist, when they identified many. Still some confusion persisted about the identity of some fauna, e.g. Sharak in Persian really means a closely related group of birds, and not a particular one.

Plants, Trees and Fruits

Among the Indian fruits Babur was full of praise of mango.

The Mango (Amb, Persian Anbak) is one of the fruits peculiar to Hindustan. Hindustanis pronounce the b in its name as though no vowel followed it .This being awkward to utter, some people call the fruit [P.] naghzak as Khwaja Khusrau does.Mangoes when good, are very good, but, many as are eaten, few are first-rate. They are usually plucked unripe and ripened in the house. Unripe, they make excellent condiments ……Taking it altogether, the mango the best fruit of Hindustan. Some so praise it as to give it preference over all fruits except the musk-melon…

Babur has also described other fruits like:

The (Sans.) Jaman (Eugenia jambolana) is another. Its leaf, except for being thicker and greener, is quite like the willows. The tree does not want for beauty. Its fruit is like a black grape, is sourish, and not very good…..

The (H.) Kamrak (Beng. Kamrunga, Averrhoa Carambola) is another. Its fruit is five-sided, about as large as 3 inches long. It ripens to yellow; gathered unripe, it is very bitter; gathered ripe, its bitterness has become sub-acid, not bad, not wanting in pleasantness….

The lote-fruit (Sanskrit ber, Zisyphus jujube) is another. Its Persian name is understood to be kanar. It is of several kinds: of one the fruit is larger than the plum; another is shaped like the Husaini grape. Most of them are not very good; we saw one in Bandir (Guallar) that was really good. The lote-tree sheds its leaves under the Signs Saur and Jausa (Bull and twins), burgeons under Saratan and Asad (Crab and Lion) which re the true rainy-season, then becoming fresh and green, and ripens its fruit under Dalu and Haut (Bucket i.e. Aquarius, and fish)….

The coco-nut palm (P. Nargil, Cocos nucifera) is another. An Arab gives it Arabic form and says narjil. Hindustan people say narikel, seemingly by popular error. Its fruit is the nut from which black spoons are made and the larger ones of which serve for guitar-bodies. The coco-palm has general resemblance to the date-palm, but has more, and more glistening leaves. Like the walnut,

the coco-nut has a green outer husk; but its husk is of fibre on fibre. All ropes for ships and boats and also cord for sewing boat-seams are heard of as made from these husks. The nut, when stripped of its husk, near one end shows a triangle of hollows, two of which are solid, the third a nothing, easily pierced. Before the kernel forms, there is fluid inside; people pierce the soft hollow and drink this; it tastes like date-palm cheese in solution, and is not bad.

Babur has described many flowers with minute details. Here is one example of hibiscus.

In Hindustan there is great variety of flowers. One is the jasun (Hibiscus rosasinensis or China rose) …It is not a grass; its tree is rather taller than the bush of the red-rose. The flower of the jasun is fuller in colour than that of the pomegranate, and may be of the size of the red-rose, but, the red-rose, when its bud has grown, opens simply, whereas, when the jasun-bud opens, a stem on which other petals grow, is seen like a heart amongst its expanded petals. Though the two are parts of the one flower, yet the outcome of the lengthening and thinning of that stem-like heart of the first-opened petals gives the semblance of two flowers. It is not a common matter. The beautifully coloured flowers look very well on the tree……

Babur's botanical insight and interest in linguistics have greatly helped scientists and historians of science. For example, when Babur first saw plantain (Banana) plants, he promptly identified it as a kind of weed or grass and not a proper plant. Surprisingly, this is botanically correct. Similarly, we now understand the origin of the word tamarind (Imli) as Babur described it as tamar-i-hind or Indian date-palm.

Time reckoning

In his memoires, Babur has discussed in detail the Indian systems of weights, measures and time reckoning. Here are Babur's descriptions of seasons:

Whereas there are four seasons in those countries, there are three in Hindustan, namely, four months are summer; four are the rains; four are winter. The beginning of their months Is from the welcome of the crescent-moons. Every three years they add a month to the year; [Babur here mentions about the intercalary month]if one had been added to the rainy season, the next is added, three years later, to the winter months, the next, in the same way, to the hot months. This is their mode of intercalation. Chait, Baisakh, Jeth and Asadh are the hot months, corresponding with the Fish, Ram, Bull and Twins ; Savan, Bhadon, Kiifir and Katik are the rainy months, corresponding with the Crab, Lion, Virgin and Balance ; Aghan, Pus, Magh and Phalgun are the cold months, corresponding with the Scorpion, Archer, Capricorn, and Bucket or Aquarius.

The people of Hind, having thus divided the year into three seasons of four months each, divide each of those seasons by taking from each, the two months of the force of the heat, rain, and cold. Of the hot months the last two, i.e. Jeth and Asadh are the force of the heat; of the rainy months, the first two, i.e. Sawan and Bhadon are the force of the rains; of the cold season, the middle two, i.e. Pus and Magh are the force of the cold. By this classification there are six seasons in Hindustan.

Babur's descriptions of divisions of time give us not only the minute details of time reckoning system prevalent in India and Central/Western Asia but also their comparative study. Babur also mentioned of performing experiments to ascertain the exact duration of a second. This can be expected only from a man of true scientific mind-set.

As in our countries what is known by the term kick gimdiiz (a day-and-night, nycthemeron) is divided into 24 part each called an hour (Ar.saa'ah), and the hour is divided into 60 parts, each called a minute (Ar. daqeeqah). The daqeeqah is about as long as six repetitions of the Fatiha with the Bismillah, so that a day-and-night is as long as 8640 repetitions of the Fatiha with the Bismillah, consists of 1440 minutes, so the people of Hind divide the night andday into 60 parts, each called a (S.) Ghari. They divide the night into four and the day into four, calling each part a (S.) pahr (watch) which in Persian is a pas. A watchman (Pas u pasban) had been heard about (by us) in those countries (Transoxania), but without these particulars. Agreeing with the division into watches, a body of g'harialis is chosen and appointed in all considerable towns of Hindustan. They cast a broad brass (plate-) thing, perhaps as large as a tabaq and about two hands'-thickness; this they call a ghari and hang up in a high place. Also they have a vessel perforated at the bottom like an hour-cup. The g'harialis put this into water and wait till it fills. For example, they will put the perforated cup into water at day-birth; when it fills the first time, they strike the gong once with their mallets; when a second time, twice, and so on till the end of the watch. They announce the end of a watch by several rapid blows of their mallets. After these they pause; then strike once more, if the first day- watch has ended, twice if the second, three times if the third, and four times if the fourth. After the fourth day-watch, when the night-watches begin, these are gone through in the same way. It used to be the rule to beat the sign of a watch only when the watch ended; so that sleepers chancing to wake in the night and hear the

sound of a third or fourth Ghari, would not know whether it was of the second or third night-watch. I therefore ordered that at night or on a cloudy day the sign of the watch should be struck after that of the Ghari, for example, that after striking the third Ghari of the first night-watch, the gharialis were to pause and then strike the sign of the watch, in order to make it known that this third Ghari was of the first night-watch, and that after striking four Gharis of the third night-watch, they should pause and then strike the sign of the third watch, in order to make it known that this fourth Ghari was of the third night-watch. It did very well; anyone happening to wake in the night and hear the gong, would know what Ghari of what watch of night it was. Again, they divide the Ghari into 60 parts, each part being called a Pal. By this each night-and-day will consist of 3,6oo Pals. They say the length of a pal is the shutting and opening of the eyelids 60 times, which in a night and-day would be 216,000 shutting and openings of the eyes. Experiment shows that a Pal is about equal to 8 repetitions of the Qul-hwwa-allah and Bismillah ; this would be 28,000 repetitions in a night-and-day.

Weights & Measures, Counting System

The people of Hind have also well-arranged measures : 8 raits = 1 masha ; 4 masha = I tank =32 raits ; 5 masha = 1 misqal = 40 raits ; 12 masha =1 tula = 96 raits ; 14 tula = 1 ser. This is everywhere fixed: 40 ser = 1 maund; 12 maund = 1 mani; 100 mani they call a manyasa. Pearls and jewels they weigh by the tank.

[Generally (S.) 1 rati = 8 rice-grains (Eng. 8 barley-corns) ; the (S.) masha is a kidney- bean ; the (P.) tank is about 2 oz. ; the (Ar.) misqal is equal to 40 raffs ; the (S.) tula is about 145 oz. ; the (S.) ser is of various values]

The people of Hind have also an excellent mode of reckoning : 100,000 they call a lak ; 100 laks equal to a kriir ; 100 kriirs equal to an arb ; 100 arbs equal to 1 kharb,100 kharbs equal to I nil,100 nils equal to1 padam; 100 padams to I sang. The fixing of such high reckonings as these is proof of the great amount of wealth in Hindustan.

It seems that *arb* is Sanskrit Arbud and *nil* is Sanskrit Nirbud. It also appears that Babur was not aware of India's great mathematical heritage. This is of course natural in the medieval India; it took 300 years more for the European Indologists to unearth India's glorious past.

Babur's interest in Science reappeared in his great grandson Jahangir, who was a leading naturalist of his time. Tuzuk-i-Jahangiri gives us many accounts of flora and fauna of that time. We shall discuss the same in another article.

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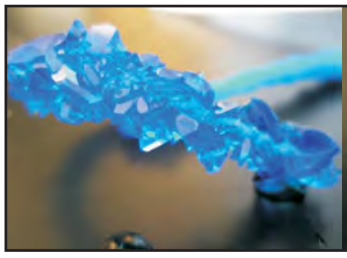
A Century of Crystallography

Kanchan Kumar Chowdhury

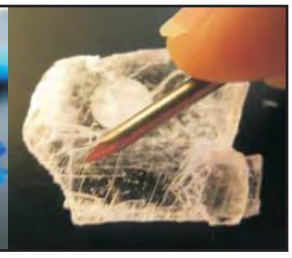
Abstract

The United Nations declared 2014 as the 'International Year of Crystallography' to commemorate 100 years since the award of Nobel Prize in Physics for the discovery of X-ray diffraction by crystals. The International Year of Crystallography 2014 highlights the continuing importance of crystallography and its role in addressing post-2015 development issues such as food security, safe drinking water, health care, sustainable energy and environmental mitigation. The present paper brings out some important applications of crystallography in our life and its future impact.

Throughout history, people have been fascinated by the beauty and mystery of crystals. They are everywhere in nature- in gemstones, glittering snowflakes or grains of salt. The study of crystals' inner structure and properties gave us deepest insights into the arrangement of atoms in the solid state and led to advancements the sciences of solid-state physics, chemistry, biology, medicine and even mathematics, by considering the symmetries behind crystalline and quasicrystalline patterns. Today this field has advanced and the technique has found applications to produce materials with predesigned and controlled properties, from a chemical catalytic agent of industrial interest to toothpaste, vitro-ceramic glass plates, very hard materials for surgerical use, or certain aircraft components. The structure of ribosome helps to understand how antibiotics work and therefore we are able to modify their structure to improve efficiency.



Copper(II) Sulfate



Rochelle Salt

A crystal is a solid substance made of atoms, molecules or ions that form regular repeating patterns called a crystal lattice. The atoms or ions in crystals are held together by attractive forces often referred to as bonds.

The hardness of a crystal results from the strength of the bonds. When mineralogists study rocks and minerals, they often test for the hardness of these materials. Scientists also study optical properties of crystals. An optical property involves the way a crystal interacts with light. Four common optical interactions with light are color, interference, birefringence, and fluorescence. Crystals often have a characteristic color due to absorption of light, for example hydrated copper(II) sulfate crystals are a characteristic royal blue color. Color may also be caused by interference.

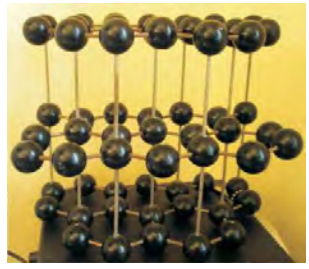
Birefringence

Crystal of Bismuth

Interference often produces rainbows due to the differences in the time that it takes for different colors of light to pass through a material. Bismuth's rainbow colors are due to the varying thickness of an oxide coating. Also referred to as double refraction, birefringence is the splitting of light inside a crystal, causing double vision when looking through the crystal.

Table salt, which has the chemical name of sodium chloride, is a white crystal with a cubic shape. It is made of sodium (Na^+) and chloride (Cl^-) ions. Sugar, ice and diamonds are all crystals. Each has their own shape. Other crystals can be formed from powders that you may have around the house. For example, the detergent booster, borax, contains sodium borate which makes crystals easily. Crystals form as a result of bonds

(attractions) between atoms, ions and/or molecules. The particles align themselves to maximize the number of attractions. For example, the Cl– and Na+ ions in sodium chloride attract each other. The unit cell is the smallest repeating portion of the crystal. The unit cell is like a brick and the entire crystal is like a brick wall.

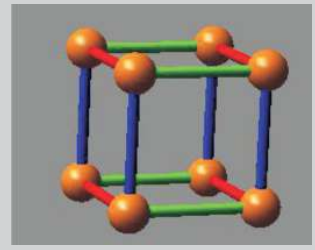



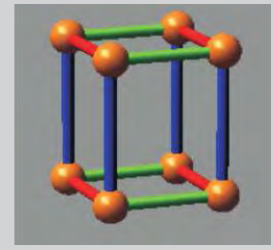
Graphite

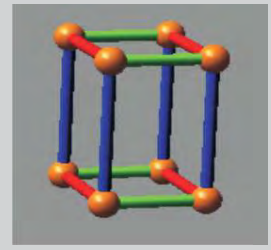
Diamond and graphite (pencil "lead") are forms of carbon. They are very different. Diamond is colorless and very hard. Graphite is black and very soft. These differences come from the different arrangement of atoms in diamond and graphite. It is now well established that a diamond lattice consists of two interpenetrating face centered cubic lattices which are displaced with respect to each other by 1/4th of the lattice spacing in each direction. A face centered unit cubic cell contains four atoms, one at the corner (actually eight corners but each shared by eight cubes) and three at face centers (actually six at the centres of six faces of a cube but each shared by two faces of adjoining cubes). Their fractional positions in the unit are:0,0,0; ½,½,0; ½,0, ½;0, ½,½; Therefore, the diamond lattice contains 8 atoms in the unit cell.

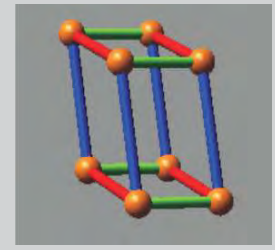

Diamond

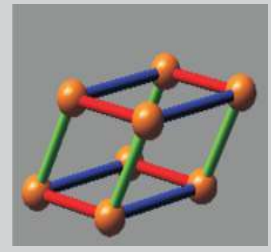
Crystals form in seven different shapes called crystal systems. The crystal systems are named cubic, tetragonal, orthorhombic, monoclinic, triclinic, hexagonal, and rhombohedral. Each crystal system has a unique shape (symmetry). For example all edges (red, green, and blue) in a cubic crystal have the same length. But in a tetragonal crystal one of these lengths (blue) is different than the other two. And in orthorhombic crystals all three are different from one another.

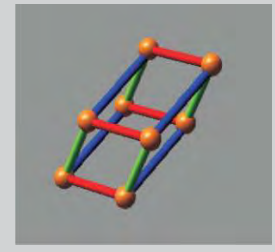

Cubic

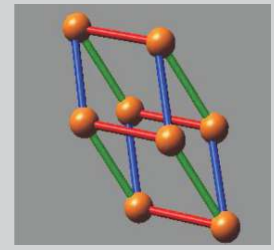

Tetragonal


Orthorhombic


Monoclinic


Hexagonal

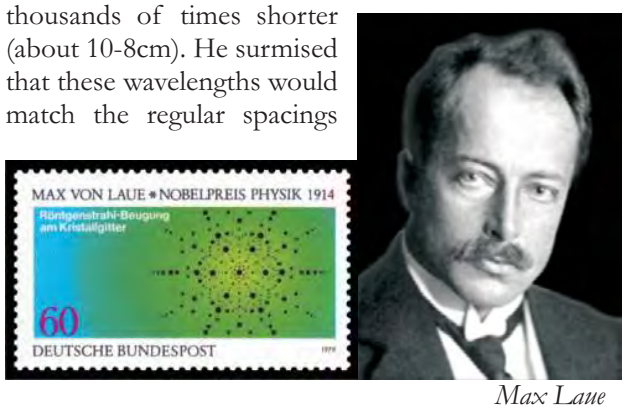

Triclinic


Rhombohedral

The history of crystallography began with the work of Johannes Kepler in the 17th century who, in 1611, wrote perhaps the first treatise on geometrical crystallography, with the delightful title, 'A New Year's Gift or the Six-Cornered Snowflake' (Strena Seu de Nive Sexangula). In this he speculates on the question as to why snowflakes always have six corners, never five or seven. He suggests that snowflakes are composed of tiny spheres or globules of ice and shows, in consequence, how the close-packing of these spheres gives rise to a six-sided figure. Kepler was not able to solve the problem as to why the six corners extend and branch to give many patterns (a problem not fully resolved to this day), nor did he extend his ideas to other crystals. Less than 200 years later, French mineralogist René Just Haüy discovered the geometrical law of crystallization.

But perhaps the most crucial leap in understanding came with the work of the father-and-son team the Braggs in 1912. They pioneered a method for uncovering how the atoms in a crystal were arranged. The development of crystallography goes hand in hand with the discovery of X-rays by Wilhelm Röntgen, who in 1895 noted that a high-voltage vacuum tube emitted an unknown type of radiation, which passed through objects to leave an image on a photographic plate.

In 1912, Max Laue established that these penetrating X-rays were like visible light, but with wavelengths thousands of times shorter (about 10-8cm). He surmised that these wavelengths would match the regular spacings between atoms in a simple salt crystal such as copper sulphate. X-rays passing through the crystalline array would thus be diffracted.

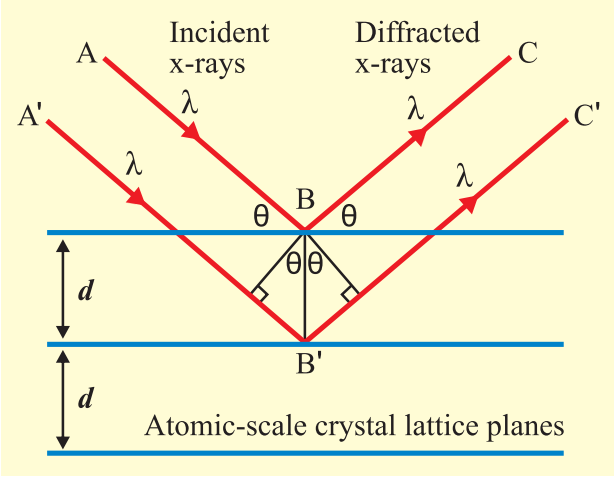


Max Laue

How exactly does the diffraction pattern obtained relate to the crystal structure? That was explained by William Lawrence Bragg while at the University of Cambridge using a beautifully simple equation known as Bragg's Law – which is now the basis of all modern crystallography.

Bragg's Law

When a crystal is bombarded with X-rays of a fixed wavelength (similar to spacing of the atomic-scale crystal lattice planes) and at certain incident angles, intense reflected X-rays are produced when the wavelengths of the scattered X-rays interfere

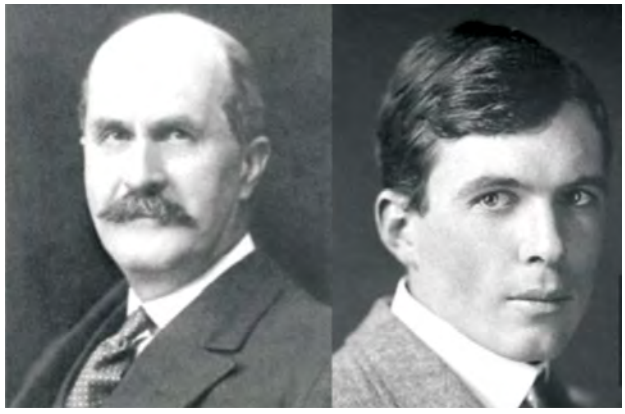


constructively. In order for the waves to interfere constructively, the differences in the travel path must be equal to integer multiples of the wavelength. When this constructive interference occurs, a diffracted beam of X-rays will leave the crystal at an angle equal to that of the incident beam. When the travel path length difference between the ray paths ABC and A'B'C' is an integer multiple of the wavelength, constructive interference will occur for a combination of that specific wavelength, crystal lattice planar spacing and angle of incidence (Θ). Each rational plane of atoms in a crystal will undergo refraction at a single, unique angle (for X-rays of a fixed wavelength).

The general relationship between the wavelength of the incident X-rays, angle of incidence and spacing between the crystal lattice planes of atoms is known as Bragg's Law and is expressed as :

$$n\lambda = 2d \sin\Theta$$

where n (an integer) is the "order" of reflection, λ is the wavelength of the incident X-rays, d is the interplanar spacing of the crystal and Θ is the angle of incidence.



William Henry Bragg *William Lawrence Bragg*

William Lawrence Bragg was only 25 when he won the 1915 Nobel Prize in physics, and remains the youngest person ever to win the Nobel Prize. Considered the father of X-ray crystallography, he was the first (together with his father) to use X-rays to determine the arrangement of atoms in simple crystals. In the following years until his retirement in 1965, he was involved with almost all the major developments in X-ray crystallography. From his early solution of scores of inorganic crystals, through his study of metallic alloys, to the solution of complex biological macromolecules such as hemoglobin and DNA, Bragg's life story is also a personal history of the first 50 years of X-ray crystallography and the birth of modern materials science and molecular biology.

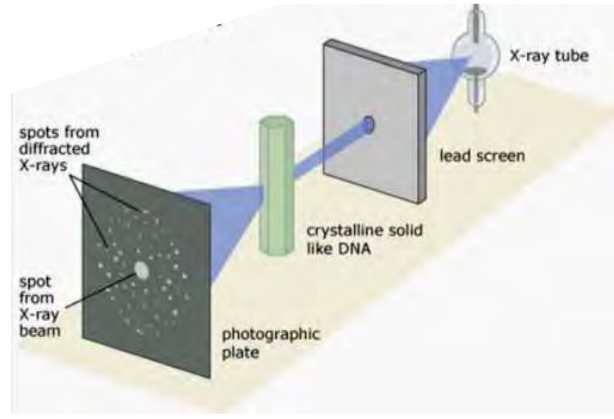
Bragg is described as a shy intellectual, a genius who used his understanding of optical diffraction to lay the foundations of X-ray crystallography one simple idea at a time. He was quick to realize that 'Bragg peaks', as we call them today, are formed by the interference of waves diffracted by planes of atoms in the crystal according to 'Bragg's law'. He was first to realize that the peak intensities, not only their positions, hold the information for unlocking the crystal structure, and recognized the importance of overcoming the 'phase problem', which he tackled using ingenious methods.

An important lesson can be learned from Bragg's attitude to research. He approached the problem of crystal structure like solving a puzzle, and believed that all the information required was contained within the diffraction pattern. He didn't care to learn the detailed chemistry or biological function of the molecules, nor

(1890-1971)
Swedish postage stamp with Braggs

did he study quantum mechanics as did all his contemporaries. It seems that Bragg didn't believe in fancy theory but rather in simple logic, grounded in his fundamental grasp of physics. Bragg invented experimental devices for doing some of his theory.

X-ray diffraction, developed in the first half of the 20th century, was one of the new technologies that made solving the structure of DNA possible. The technique works on crystals, a kind of molecule with a regular, repeating structure. When X-rays are aimed through a sample, they are bent or diffracted in different directions depending on the locations of the atoms in the sample, and the final direction of the X-rays can be



X-ray Diffraction Technique

recorded on film. Because the X-rays must travel through many layers of atoms, it's important that the atoms always occur in the same crystalline arrangement. If they don't, the X-rays are bent into overlapping patterns, leaving the results a fuzzy, indistinct blur. However, if the structure has a repeating arrangement of atoms, they leave a pattern of sharp, clear spots. Different structures scatter the X-rays into different characteristic patterns.

Even though scientists couldn't directly observe the atoms within the crystal, they could work backward from X-ray diffraction patterns to reconstruct the three-dimensional structure that produced the scattering. This works a little like trying to figure out how tall a person is by looking at his or her shadow. Depending on the angle of the sun, the shadow might be longer or shorter, but if we could compare many pictures of their shadow at different times of day, we would eventually be able to figure out how tall they were. Similarly, scientists compare many "shadows," or X-ray diffraction patterns, cast by a crystal to determine the arrangement of atoms within it.

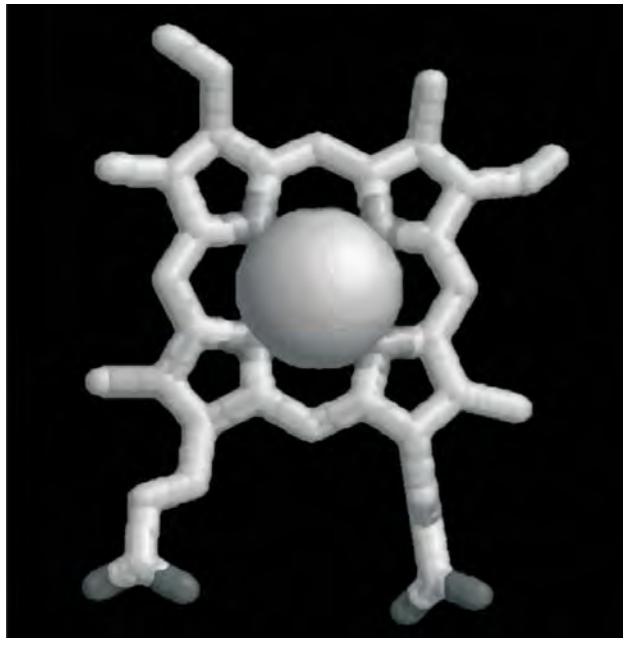
An essential step in X-ray crystallography is growing high-quality crystals. The best crystals are pure, perfectly symmetrical, three-dimensional repeating arrays of precisely packed molecules. They can be different shapes, from perfect cubes to long needles. Most crystals used for these studies are barely visible (less than 1 millimeter on a side). But the larger the crystal, the more accurate the data and the more easily scientists can solve the structure. Crystallographers grow their tiny crystals in plastic dishes. They usually start with a highly concentrated solution containing the molecule. They then mix this solution with a variety of specially prepared liquids to form tiny droplets (1-10 microliters). Each droplet is kept in a separate plastic dish or well. As the liquid evaporates, the molecules in the solution become progressively more concentrated. During this process, the molecules arrange into a precise, three-dimensional pattern and eventually into a crystal. Sometimes, crystals require months or even years to grow. The conditions - temperature, pH (acidity or alkalinity), and concentration - must be perfect. And each type of molecule is different, requiring scientists to tease out new crystallization conditions for every new sample. Even then, some molecules just won't cooperate. They may have floppy sections that wriggle around too much to be arranged neatly into a crystal. Or, particularly in the case of proteins that are normally embedded in oily cell membranes, the molecule may fail to completely dissolve in the solution.

Copper Sulfate - $CuSO_4$ - One of the first crystals to be examined by x-ray diffraction.

Crystallography, can be broken down into two main areas - the study of small molecules and the study of large molecules. X-ray crystallography is the fundamental research tool that shaped our notion on biological structure & function at the molecular level. It generates the information vital to understand life processes by providing the information required for creating accurate three-dimensional models. The power of this method inspired continuous efforts and spectacular innovations, which vastly accelerated its incredible expansion. Consequently, over the last six decades biological crystallography has produced a constantly growing number of structures, some of which were considered formidable. This remarkable advance yielded numerous new insights into intricate functional aspects.

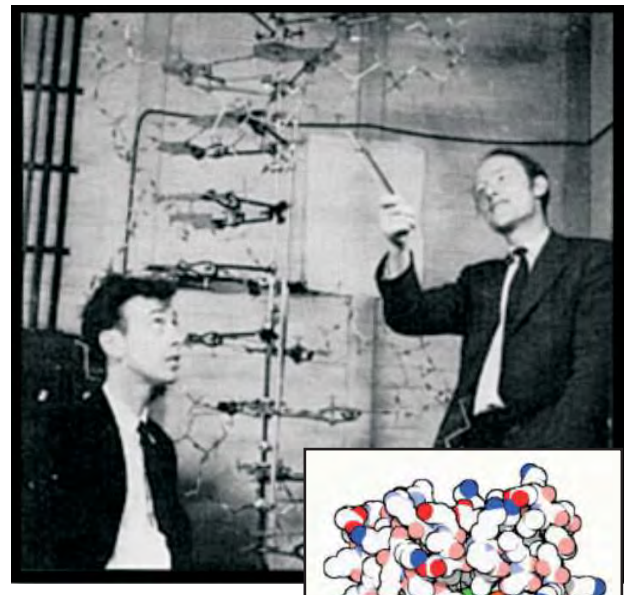
Proteins, macromolecules involved in everyday functions of the body such as transporting oxygen and chemicals in blood, forming major components of muscle and skin, and fighting disease, come in over 100,000 varieties. Active sites on molecules of proteins, when inappropriately triggered or absent, can cause disease or an unwanted function. Scientists seek to locate those active sites so drug designers can understand their function and then, in some cases, work to block them or render them inactive. For example, the anti-inflammatory drug ibuprofen works on a specific protein, which is involved early in the signaling process that tells your body that inflammation should occur. Blocking the active site on this protein prevents or reduces the inflammation.

The first known published observation of the crystallization of a protein was made by F.L. Hunefeld in 1840 at Leipzig University in Germany. While working with hemoglobin, Hunefeld obtained flat, plate-like crystals of this protein when he pressed the blood of an earthworm between two slides of glass and allowed the blood to dry very slowly. In 1851, Otto Funke, another German researcher, published a series of articles in which he described growing hemoglobin crystals by successively diluting red blood cells with a solvent such as pure water, alcohol or ether, followed by slow evaporation of the solvent from the resulting protein solution.



Molecular structure of the heme ring in the hemoglobin molecule

Early on, scientists grew crystals solely to purify proteins. Not until the 1930's did researchers begin to focus their attention on crystals as a source of structural information about protein molecules. They turned to X-ray diffraction, a procedure in which a pencil-lead-sized X-ray beam is directed at a crystal. The X-ray beam is scattered by the crystal, producing a signal that results in tiny pinpoints that can be recorded on film. Data from this recorded X-ray diffraction pattern has a direct relationship to the protein's molecular structure and can be used to help reveal the structure of a molecule of the particular protein under investigation. By the 1960's, scientists were investigating the molecular structures of an abundance of crystals grown by biochemists.



DNA Structure

Myoglobin Structure

The full flowering of biological crystallography began in the 1960s, heralded by the 1964 Nobel Prizes in Medicine and Chemistry. The awards to Crick, Watson and Wilkins for the structure of DNA and to Kendrew and Perutz for the first protein structures (myoglobin and haemoglobin) both depended on X-ray diffraction.

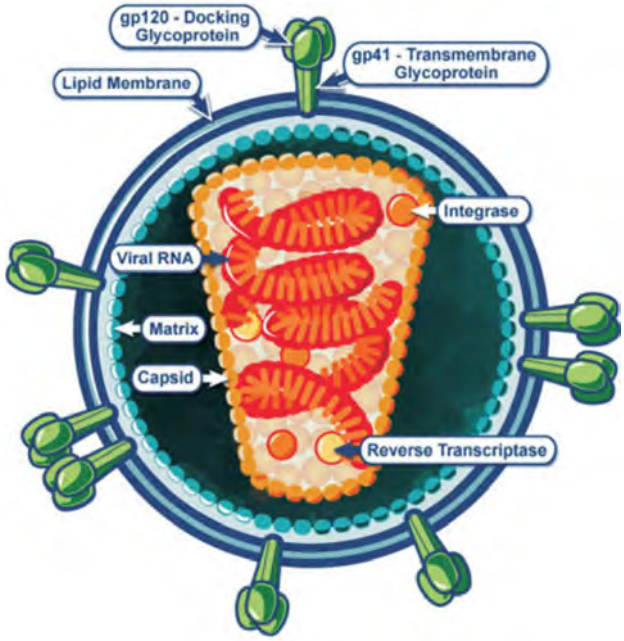
Myoglobin was the first protein visualized in three dimensions at the atomic level by X-ray crystallography, laying the foundation for a new era of biological understanding. For this discovery, John Kendrew and Max Perutz shared the 1962 Nobel Prize in Chemistry. In 1959 Max Perutz, whose methodological work had been crucial to Kendrew's success, determined the structure of hemoglobin, a protein closely related to myoglobin and the second to be analyzed by X-ray crystallography. It can be said fairly that without crystallography the molecular biology of today could not exist.

A living cell is extremely crowded, with thousands of different proteins and other molecules jostling for space (the total protein concentration is estimated at about 30 g/L). In this environment, specificity is everything; a protein must perform its own task,

efficiently and without error, and the 3D structure of a protein is critical, defining its chemistry and the spatial constraints on its substrates. Secondly, structural knowledge provides new opportunities for applications, in areas such as structure-based drug design, or in the development of new tools in biotechnology.

Historically, the discovery of drugs has largely been a process of trial-and-error. The targets of these medicines were unknown and side effects were discovered the hard way. As more has been learned about the molecular basis of disease, it has become possible to develop drugs specifically against deliberately-chosen targets. Crystallography, and knowledge of protein 3D structure, is now playing an ever-increasing role in this approach to new medicines, as is illustrated by drugs developed against two viral diseases, HIV-AIDS and Influenza.

The near-panic that came with the AIDS epidemic of the 1980s led to the first triumph for crystallography and structure-based drug design. The goal in this approach is to find a protein that is critical to the survival or spread of the infectious agent, solve its structure and design specific inhibitors against it. In the fight against AIDS, two key targets, the HIV protease and the HIV reverse transcriptase, were quickly crystallized and their structures solved. The HIV protease proved to be druggable and within seven years the first drugs were in the clinic. Although not a cure, the drugs continue to be improved, and the disease is now manageable. The beauty of the structure-based approach is that knowledge of exactly how a molecule binds to its target enables a medicinal chemist to see exactly where a substituent might be added, or where it cannot be, during the difficult process of optimization.



Structure of HIV

In 1999, researchers determined the crystal structure of a complete ribosome for the first time. The work was a technical triumph for crystallography. Even today, the ribosome remains the largest complex structure obtained by crystallography.

Ribosomes make the stuff of life. They are the protein factories in every living creature, and they churn out all proteins ranging from bacterial toxins to human digestive enzymes. To most people, ribosomes are extremely small —tens of thousands of ribosomes would fit on the sharpened tip of a pencil. But to a

Examining ribosomal structures in detail will help researchers better understand the fundamental process of protein production. It may also aid efforts to design new antibiotic drugs or optimize existing ones.

structural biologist, ribosomes are huge. They contain three or four strands of RNA and more than 50 small proteins. These many components work together like moving parts in a complex machine - a machine so large that it has been impossible to study in structural detail until recently. Ribosomes are complex molecular machines that serve as the primary site of biological protein synthesis. They are composed of two independent subunits of unequal size, which associate upon initiation of protein biosynthesis. Due to their enormous size, tendency to deteriorate, and functional heterogeneity, ribosomes are extremely challenging to crystallize. For determining the detailed structure and mechanism of the ribosome Venkatraman Ramakrishnan, Thomas A. Steitz and Ada E. Yonath were jointly awarded the Nobel Prize in Chemistry in 2009.

The complexity of biological systems demands exquisite control of specificity and a crucial role for three-dimensional structure. Structural biology thus provides a natural bridge between chemistry and biology by its ability to define biological systems and mechanisms at an atomic level. Remarkable technological advances in X-ray crystallography over the past 20 years, coupled with developments in NMR and cryo-electron microscopy (not discussed in this article, but highly complementary) now make biological structural information highly accessible. Many of the steps in structure determination are beginning to be automated. The frontier has shifted to the more challenging systems – membrane proteins, protein-protein complexes, biological machines and assemblies – for which the key requirements are to find tractable forms for analysis. Behind these frontier targets, however, the structures of simpler proteins will provide the knowledge that fuels many applications in biomedicine, biotechnology and nano-science. Above all, this is still discovery science, with many more of Lawrence Bragg's gold nuggets yet to be found.

Future Challenges

The following are some examples of how crystallography can :

- *help improve water quality in poor communities, for instance, by identifying new materials which can purify water for months at a time, such as nanosponges (tap filters) and nanotablets. It can also help to develop ecological solutions to improve sanitation.*

- *develop new products which lower home's energy consumption (and heating bill) while curtailing carbon emissions, such as insulating materials. It can also identify new materials which reduce the cost of solar panels, windmills and batteries while making them more efficient, to reduce wastage and improve access to green technologies.*

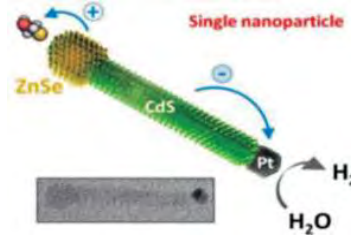
- *contribute to the development of ecological construction materials in developed and developing countries. It can also help to reduce pollution by replacing chemical solvents with 'green' inorganic solvents based on ionic liquids and CO2. It can help to reduce mining waste and related costs by contributing to methods which selectively extract only the materials required.*

- *tackle the growing resistance of bacteria to antibiotics, for instance. Together with Venkatraman Ramakrishnan and Thomas Steitz, crystallographer Ada Yonath has managed to determine the structure of the ribosome and the way it is disrupted by antibiotics. Ribosomes are responsible for the production of all proteins in living cells, including those of humans, plants and bacteria. If the work of the ribosome is impeded, the cell dies. Ribosomes are a key target for antibiotics, as antibiotics are able to attack the ribosomal activity of harmful bacteria while leaving human ribosomes untouched.*

Latest R&D News in Crystallography

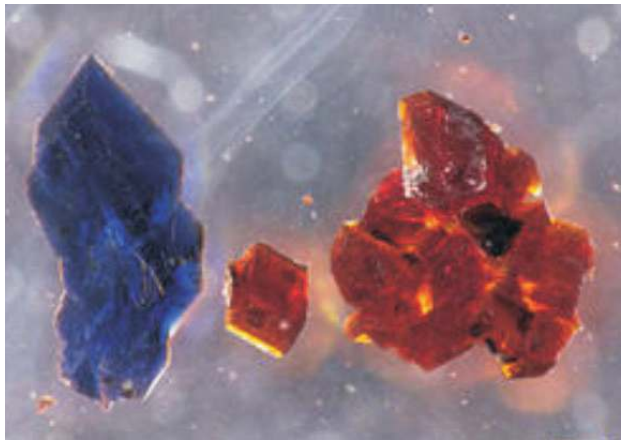
A. Researchers synthesize Inorganic Nano-crystals that harvest Solar Energy

One of the limiting factors for the popularity of solar energy is the lack of durability of light-absorbing materials. Scientists at Bowling Green State University have developed a synthesis method for two inorganic nanocrystals that are each tougher than their organic counterparts. The liquid phase of these materials can produce hydrogen gas or an electric charge. The article, published in Journal of Visualized Experiments (JoVE),



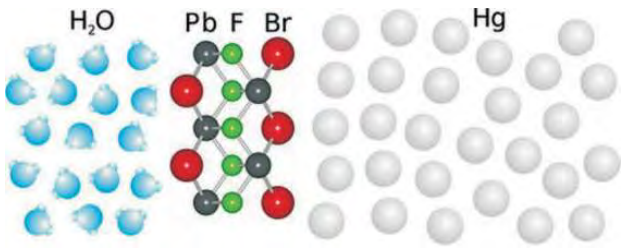
B. *A Crystal of a Different Color*

Chemists have unexpectedly made two differently colored crystals—one orange, the other blue—from one chemical in the same flask while studying a special kind of molecular connection called an agostic bond. The discovery, reported in *Angewandte Chemie International Edition,* is providing new insights into important industrial chemical reactions such as those that occur while making plastics and fuels. One flask of chemicals gives rise to either blue or orange crystals.



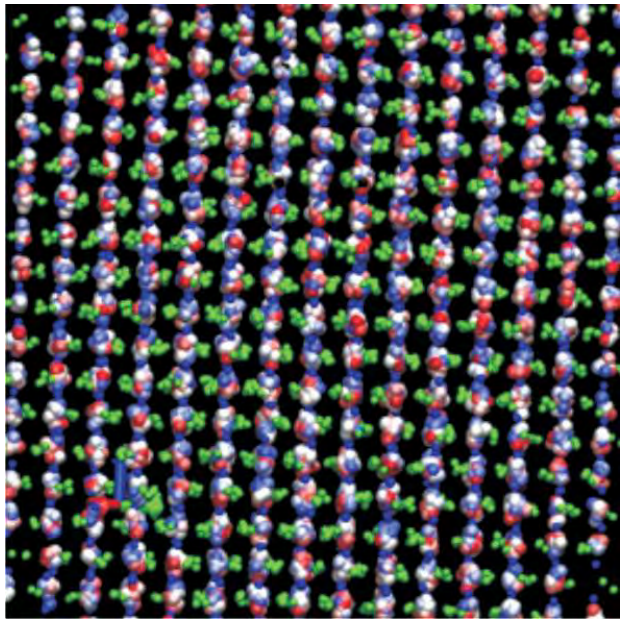
C. *Nano-crystals grow from Liquid Interface*

An international collaboration of scientists has discovered a unique crystallizing behavior at the interface between two immiscible liquids that could aid in sustainable energy development. Liquid interface behavior cannot be investigated at atomic level by most modern methods. Only brilliant X-rays at world-leading light sources can investigate this type of important chemical processes. The result is reported on in the *Proceedings of the National Academy of Science* in an article titled "In situ x-ray studies of adlayer-induced crystal nucleation at the liquid-liquid interface". The image shows the Illustration of the nano-layer at the liquid interface between the salt solution and mercury. Physicists from Kiel University discovered the formation of an ordered crystal of exactly five atomic layers between the two liquids with brilliant X-rays.



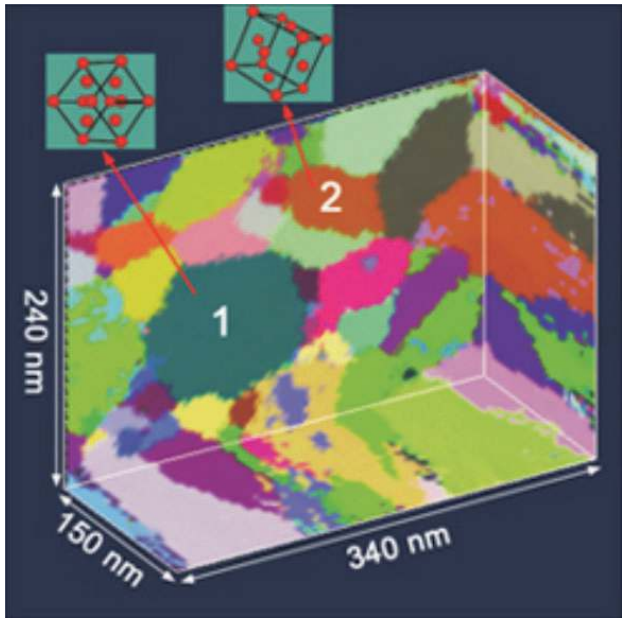
D. *Crystals for Efficient Refrigeration*

Researchers at the Carnegie Institution have discovered a new efficient way to pump heat using crystals. The crystals can pump or extract heat, even on the nanoscale, so they could be used on computer chips to prevent overheating or even meltdown, which is currently a major limit to higher computer speeds. The research is published in the Physical Review Letters. The image shows a molecular dynamics simulation of lithium niobate under a time varying electric field, which changes the sign of the polarization. Red is niobium, green is oxygen, and lithium shows a range of colors for different time steps. The niobium and oxygen are shown only for one time step for clarity.



E. *Looking inside Nano-materials in Three Dimensions*

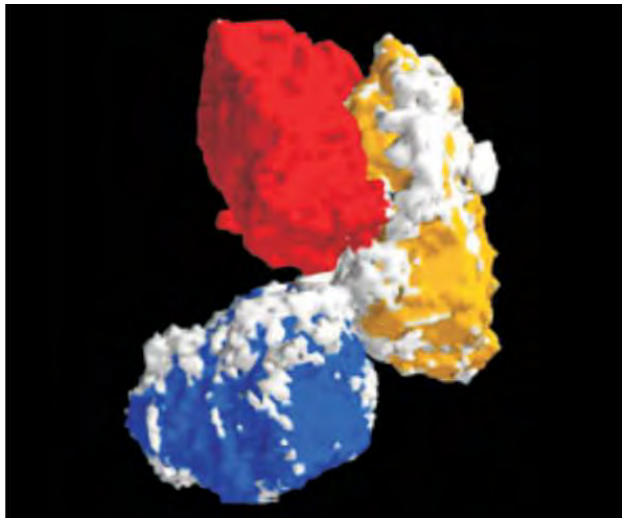
An international team of scientists have developed a new technique using a transmission electron microscope (TEM) that allows 3D mapping of the crystal structure inside a material. Unlike previous methods using x-rays, the TEM can determine structures down to a nanometer in size. An example of such a 3D map is given in the figure, showing the arrangement of crystals in a 150nm thick nano-metal aluminum film. The crystals have identical lattice structure (arrangement of atoms)



but they are orientated in different ways in the 3D sample as illustrated by the labels 1 and 2. The colours represent the orientations of the crystals and each crystal is defined by volumes of the same colour. The individual crystals of various sizes (from a few nm to about 100 nm) and shapes (from elongated to spherical) are clearly seen and mapped with a resolution of 1 nanometer.

F. X-rays Create a Window on Glass Formation

Scientists have for the first time visualized the transformation of powder mixtures into molten glass. A better understanding of this process will make it possible to produce high quality glass at lower temperatures, leading to significant energy savings in industrial glass manufacturing. The results are published in the Journal of the American Ceramic Society. The image showing the reaction between a grain of sodium carbonate (red) and two grains of silica (blue and yellow). These reactions produced sodium silicates, the precursors of glass. The grain of sand measures about 100 nm across.



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Design and Fabrication of a Universal Robotic Arm

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Abstract

In engineering and technological fields, especially in manufacturing industry, a large fraction of work is repetitive. Judicious application of automation is expected to make optimum utilization of machine and man power. Every industrialist in India cannot afford to transform his units from manual to semi-automatic or fully automatic ones, as automation is not less costly. The basic objective of this project is to develop a versatile and low cost robotic arm which can be utilized in industry, etc. for several applications such as welding, cutting with high accuracy, painting and lifting and gripping light and medium loads with as less as force required without damaging the object. This robotic arm is expected to be used for doing various types of work maintaining efficiency, economy and enhancing productivity.

1. Introduction

In this paper, steps for designing and fabricating a universal robotic arm are detailed such that any interested person can build up a robot according to his own need. The robot arm is such constructed that it becomes

- cost effective, light weight and safe,
- a combination of simple mechanisms, and
- versatile with all possible movements within its working range and can be used in multipurpose operations in industries.

2. Formulation of Kinematic Equations

The universal robotic arm considered for fabrication is planned to have 3 links with 4 degrees of freedom as shown in Fig.1.

Through forward kinematics, using given joint variables, end effector position and orientation $(x,y,z,\theta_1,\theta_2,\theta_3)$ would be evaluated.

Homogeneous[1] matrix T_0^n
-specifies the location of the i^{th} coordinate frame w.r.t. the base coordinate system
-chain product of successive coordinate transformation matrices of T_{i-1}^{i}

$$T_0^n = T_0^1.T_1^2.T_2^3. \ \ldots\ldots\ldots\ .T_{n-1}^n$$

$$= \begin{bmatrix} R_0^n & P_0^n \\ 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} n & s & a & P_0^n \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \ldots\ldots (i)$$

$$A_i = R_{z,\theta_1} Trans_{z,2} R_{y,\theta_2} Trans_{z,11} R_{y,\theta_3} Trans_{x,15}$$

$$= \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\theta_2 & 0 & \sin\theta_2 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_2 & 0 & \cos\theta_2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\cdot \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 11 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\theta_3 & 0 & \sin\theta_3 & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta_3 & 0 & \cos\theta_3 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 15 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta_1\cos\theta_2\cos\theta_3 - \cos\theta_2\sin\theta_2\sin\theta_3 & -\sin\theta_1 & \cos\theta_1\sin\theta_2\cos\theta_3 + \cos\theta_1\cos\theta_2\sin\theta_3 \\ \sin\theta_1\cos\theta_2\cos\theta_3 - \sin\theta_1\sin\theta_2\sin\theta_3 & \cos\theta_1 & \sin\theta_1\sin\theta_2\cos\theta_3 + \sin\theta_1\cos\theta_2\sin\theta_3 \\ -\sin\theta_2\cos\theta_3 - \cos\theta_2\sin\theta_3 & 0 & \cos\theta_2\cos\theta_3 - \sin\theta_2\sin\theta_3 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\begin{matrix} 11\cos\theta_1\sin\theta_2 + 15\,(\cos\theta_1\cos\theta_2\cos\theta_3 - \cos\theta_1\sin\theta_2\sin\theta_3) \\ 11\sin\theta_1\sin\theta_2 + 15\,(\sin\theta_1\cos\theta_2\cos\theta_3 - \sin\theta_1\sin\theta_2\sin\theta_3) \\ 2 + 11\cos\theta_2 + 15\,(-\sin\theta_2\cos\theta_3 - \cos\theta_2\sin\theta_3) \\ 1 \end{matrix}$$

$\ldots\ldots$ (ii)

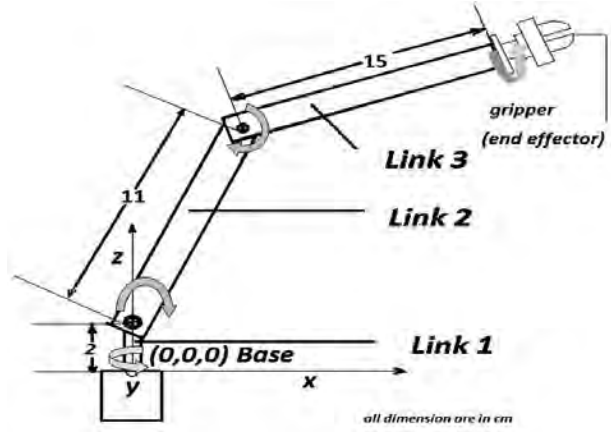

Figure 1. Sketch of Robot Arm with Dimensions

3. Gripping Mechanism with Exact Pressure

The formula W=2μF has been used to sense the exact pressure to be given by the gripper. The gripper is to be controlled by a servo motor and the gripping pressure will be increased up to an optimized value to be controlled by the microcontroller. By this, an egg can also be gripped by this gripper without being damaged.

This is possible when the object weight is sensed by the sensorbeforehand[2].

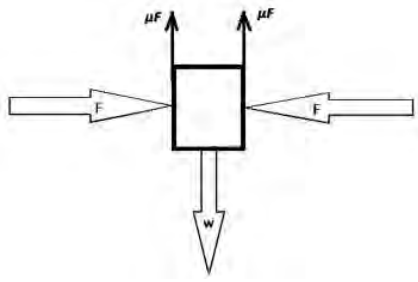

Figure 2. Free Body Diagram of the Object to be gripped

4. Design Approach

The basic design process starts with the matrix generation thus constitutes the motion of the servos and the links.

4.1. Positioning

Positioning means the method to move the end effector at its proper destination. The arm can do this easily by simply rotating its servos. After drawing the line diagram of the arm, it is easy to formulate the three governing equations to describe the locus of the end effector. Equations contain 6 variables, 3 of those are angular and rest three are in length units. As the length of links is constant, one can easily use the variables related to length as constants. So formulated are governing equations with the rest of the angular variables, and related matrices are generated[3,4].

When the matrix is formed, one can multiply them to find the matrix of the end effector which is dependent upon the movement of other links. The final 3x3 matrix can lead to get the final equation and solving it in Mathematica 9.0 one can easily get the angular values.

4.2. Gripping

Gripping is a part and parcel of robotic arm. To grip light and delicate objects one should not apply huge force to grip it, which may result in breaking or damaging the object. Moreover, to save energy one must grip the object with optimum force needed that is dependent upon the weight of the body and the co-efficient of friction between the gripper and the body to be gripped as per equation $W=2\mu F$.

4.3. Governing equation formation

After formulating the matrix of the movement of the end effector, the main task is to form the Governing Equation representing the locus of the end effector. Formation and solving of equation has been done in Mathematica 9.0. The governing equations are as follows :

$$11\cos\theta_1\sin\theta_2 + 15(\cos\theta_1\cos\theta_2\cos\theta_3 - \cos\theta_1\sin\theta_2\sin\theta_3)=X \quad \ldots\ldots \text{(iii)}$$
$$11\sin\theta_1\sin\theta_2 + 15(\cos\theta_2\cos\theta_3\sin\theta_1 - \sin\theta_1\sin\theta_2\sin\theta_3)=Y \quad \ldots\ldots \text{(iv)}$$
$$2 + 11\cos\theta_2 + 15(-\cos\theta_3\sin\theta_2 - \cos\theta_2\sin\theta_3)=Z \quad \ldots\ldots \text{(v)}$$

Where, X, Y, Z represents the co-ordinates of the desired position.

These 3 equations are used to solve the 3 variables, $\theta_1, \theta_2, \theta_3$ If co-ordinates of the final location are (5,5,15), then solving the equation in Mathematica9.0 one can get the following set of values in radian,

$$\theta_1=0.785,\ \theta_2=-0.712,\ \theta_3=0.395$$

Putting these values in the Arduino Interface one can get the desired movement.

5. Fabrication and Final Assembly

5.1. Base

At first, the base is made with a specific design such that all the links, motors and sensors are easily assembled as per the design, and the arm can easily rotate and reach all the positions within its working range.

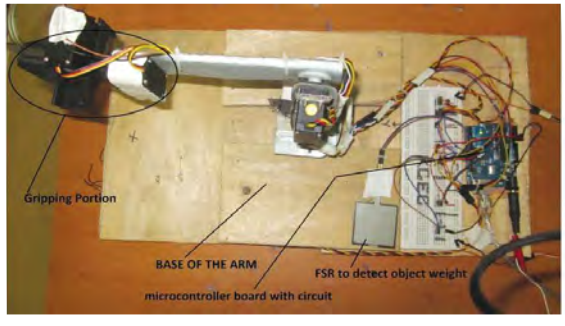

Figure 3. Base of the Arm

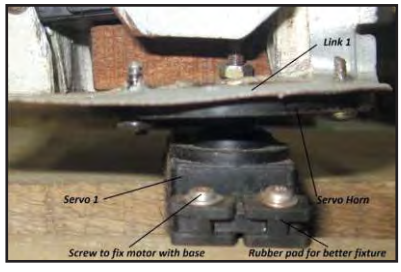

Figure 4. Image of joined Links

5.2. Links

Three aluminium (Al) plates duly bent suitably to make channel sections are used for constructing the links. Joints between the links are made revolute joints. These links carry the weight of motors, other links and loads to carry by the end effector. These links provide the working area which the robotic arm can reach up to [5].

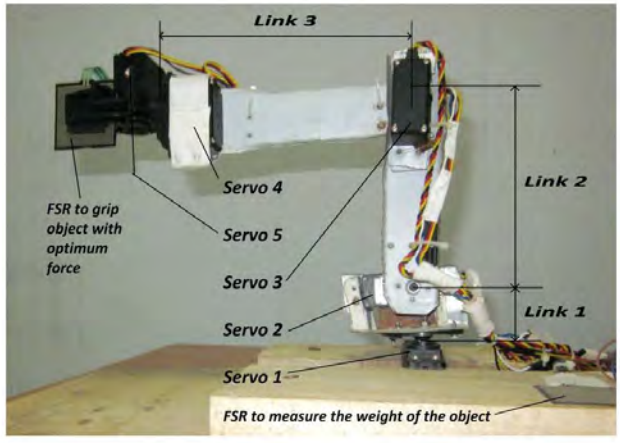

Figure 5. Links with Motors

Links are joined by simple screw joints and nut bolt joint with the servo horn. Servo1 is joined with base by simple screw joint.

5.3. Motors

In the present work, servo motors are used. Three servo motors, servo1, servo2, servo3 are employed for smooth rotation, servo4 is used for alignment purpose and servo5 is utilised for gripping purpose. Two types of servo motors are used in this work. Their specifications are as follows :

Figure 6. Servo HS-311

Specifications of Hitec Servo[6] HS-311 are :

3 pole type motor, Nylon bearing

Operating Voltage :	4.8 - 6.0 Volts
Torque at 4.8V :	42 oz/in (3.0 kg/cm)
Torque at 6.0V :	51 oz/in (3.7 kg/cm)
Dimensions :	1.57 x 0.78 x 1.43 in
	(39.88 x 19.81 x 36.32 mm)
Weight :	1.51 oz (42.81 gm)

Having light weight, low cost, fulfilling the torque required are the reasons for selecting this standard economy servo.

Specifications of Hitec Servo[7] HS 645MG that is also used in this work are given below :

Metal Gear Dual Ball Bearings

Torque at 4.8V:	107 oz - in (8 kg-cm)
Torque at 6.0V:	133 oz - in (10 kg-cm)
Dimensions:	1.59 x 0.77 x 1.48 in.
	(40.39 x 19.56 x 37.59 mm)
Weight :	1.94 oz (55 gm)

The reason behind selecting this servo is that it fulfils the torque needed within affordable price and rotates with angular precision too.

Figure 7. Servo HS-645MG

5.4. Micro Controller

In this present work, a microcontroller is chosen for the embedded application, in contrast to a microprocessor used in personal computers or other general purpose applications. The specification of the microcontroller used is given below :

Figure 8. Arduino Microcontroller

Arduino[8] Uno R3 :

Microcontroller	atmega328
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	14
Clock Speed	16 Mhz

Purpose of selecting this microcontroller is that it is quite user friendly, having an open source license, and also has wide variety of applications.

5.5. Sensors

In this work, FSR (force sensitive resistor)[9] type sensor is used. A force-sensing resistor is a material whose resistance changes when a force or pressure is applied. The force sensitive resistor (FSR) used has the following specification :

Overall length : 3.5"
Overall width : 1.75"
Sensing area : 1.75 x 1.5"
Range 10gm - 500 gm.

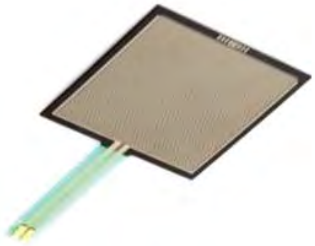

Figure 9. FSR

This is a resistor and when more force is applied on it, resistance increases and the value can be mapped in between 0 to 1023.

5.6. Gripper

In this work, used gripper detail is given below :

Capacity : up to 200gm
Openings : 3.5cm
Servo Controlled : 2

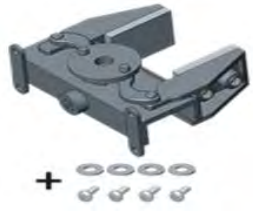

Figure10. Gripper

5.7. Assembly

First the base is constructed. When the base is ready, other parts can be fitted on it. A servo motor (servo1) is attached with base in upward direction (z axis). Link1 joins servo1 and servo2. Servo2 rotates around y axis. Link2 starts from the point of servo2 and end at the servo3. Similarly servo3 rotates around z axis and it holds link3. At the end of link3 there is another motor (servo4) which can rotate the gripper. The joints are temporary for easy dismantling to transfer to the work place. Gripper is the last and main holding part which is able to grip objects with certain dimensions. A 10K rotary potentiometer is used for rotating servo4 in a desired angle for gripping an inclined object.

The pressure sensor has two parts. One is attached on the base and measures the weight and calculates how much force is required to hold and carry, and another is attached with the gripper. The microcontroller and breadboard are fixed with base with screw joints. These parts are joined in such an array that it never hampers or creates obstruction on rotating paths.

5.8. Circuits

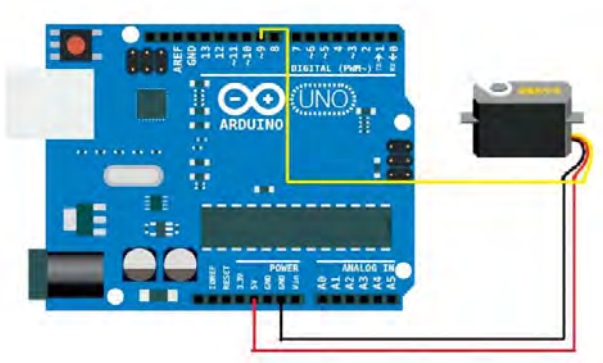

Figure 11. Servos connection with Arduino

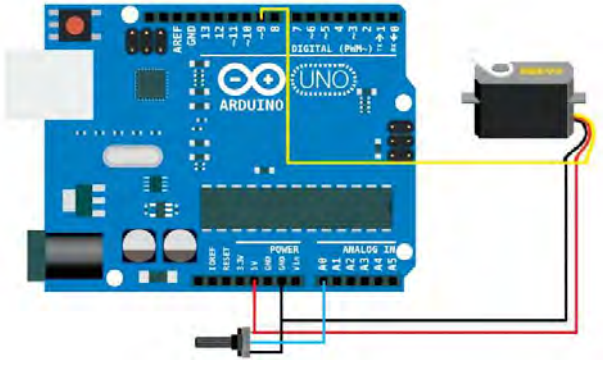

Figure 12. Servo4 and Potentiometer connection with Arduino

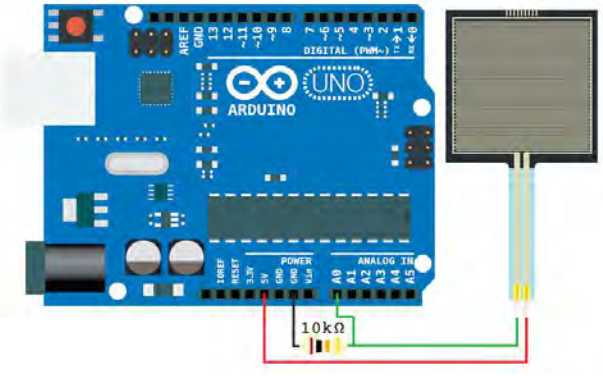

Figure 13. FSR connection[10] with Arduino

After getting all the mechanical part assembled the next step is to ensure that all the circuits are properly connected and insulated. Here all the circuit has been made by both side male header jumper wire. The four servos (servo1, servo2, servo3, servo5) are completely operated by the microcontroller after processing the digital signals from the user and the servo 4 is operated directly from user analogue signals (10K Rotary Potentiometer Signals). All the standard servos have 3 ports with standard colour code: GND (Black), +5V (Red), Signal (Yellow). In the fig.12 the connected potentiometer is completely operated by the user to select a desired angle of the tilted object. Next to all servos two FSRs have to connect with their desired analogue port of the Arduino UNO microcontroller. In this FSR two ports are present one is connected in +5V and other is connected in GND through a 10K? resistor in series. After connecting this circuit one signal is required from this FSR. So a wire is connected directly from FSR GND port to the A0 analogue pin in the board. According to this programme servo mappings are tabulated below.

Name of Servos	*Connected Arduino Digital Pin No.*
Servo 1	11
Servo 2	10
Servo 3	9
Servo Grip (Servo 5)	5
Servo Grip Rotor (Servo 4)	6

One can install the Arduino software to pc, which is available on www.arduino.cc. And using an USB cable, one can easily transfer the written programme to the Arduino board for operating the arm successfully. A sample programme is given in the appendix.

5.9. Test Results

The robotic arm has been tested after fabrication. It has been tested with different set of coordinates corresponding to the different angular rotations of each servo for its positional accuracy.

To grip a light and delicate object, it has been tested with mobile phones, flexible plastic tubes and thermocol block with concentrated load. In each test of gripping, taking the value of frictional coefficient with the gripping surface and the object surface is a vital issue. The gripper's surface has rubber pad for easy gripping. Frictional coefficient value between surfaces of rubber and mobile glass is 0.6, between rubber and plastic tube is 0.7, and between rubber and thermocol is 0.65. With these friction coefficient values, gripping forces have been calculated, and it has been found to work satisfactorily. For performing a specific task accurately, positioning and selecting the value of frictional co-efficient is to be made properly.

6. Conclusion

The fabricated Universal Robotic Arm worked properly. However, scope for betterment of the product does exist and further modification of the arm is possible for increasing strength, accuracy, capability and flexibility. Using proper tools, one can add to precision during fabrication, which will result in a better design. Reducing vibration by using different materials may lead to better accuracy. Degrees of freedom can be increased by using more servos thus increasing its flexibility. Force Sensitive Resistor (FSR) is the sensor that is a basic need of the project. Using more capable sensors means more capability of the arm. Programme development is needed to fit a situation. This robotic arm can be adapted for various industrial applications if it is fabricated suitably for the specific tasks.

Acknowledgement

We find an auspicious moment to express my sincere thanks and heartfelt gratitude to Dr. Santanu Das, Head, Department of Mechanical Engineering, Kalyani Govt. Engineering College, Kalyani for offering us a real life project and untiring endeavour throughout the course of the assignment to drive home subtle nuance of the work at every step by their relentless guidance, invaluable advice, persistent encouragement, perpetual feedback which made the daunting task much easier to bear.

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Appendix

```
#include <Servo.h>                    //includes the servo functions in this program
// Object for 3 arm servo
ServoservoOne;                        //servoOne is Servo Motor
ServoservoTwo;                        //servoTwo is Servo Motor
ServoservoThree;                      //servoThree is Servo Motor
// Object for force generating servo
Servo servoGrip;                      //servoGrip is Servo Motor (Servo 5)
Servo servoGripRoto;                  //servoGripRoto is Servo Motor (Servo 4)
intfsrOne = 0;                        //the analog reading from the FSR resistor set to 0
intfsrTwo = 0;                        //the analog reading from the FSR resistor set to 0
int fsr1 = 0;
int fsr2 = 0;
floatpos = 0;                         //initailize position for all four servo
float rad = 0;                        //initalizeposition  for radian value input
intpotpin = 0;                        //value of potentiometer for ServoGripRoto
void setup()
{
servoOne.attach(11);                  //servoOne is attached in port 11
servoTwo.attach(10);                  //servoTwo is attached in port 10
servoThree.attach(9);                 //servoThree is attached in port 9
servoGrip.attach(5);                  //servo for grip is attached in port 5
//servoGripRoto.attach(6);            //servo for gripper rotation  is attached in port 6
Serial.begin(9600);                   //begin the serial port with 9600 baud
}
void loop()
{
// Rotation of servoOne
{
pos=180*7*(rad)/22;                   //put the desired angular value in radian
pos=map(pos,-90,90,0,180);
servoOne.write(pos);
}
// Rotation of servoTwo
{
pos= 180*7*(rad)/22;                  //put the desired angular value in radian
pos=map(pos,-90,90,0,180);
servoTwo.write(pos);
}
// Rotation of servoThree
{
pos= 180*7*(rad)/22;                  //put the desired angular value in radian
```

```
pos=map( pos, 90 , -90 , 0 , 180 ) ;
servoThree.write(pos);
}
// rotate the gripper
{
pos = analogRead(A2);                    // reads the value of the potentiometer (0 to 1023)
pos = map(pos, 0, 1023, 0, 180);         // scale it to use it with the servo (value between 0 and 180)
servoGripRoto.write(pos);                // sets the servo position according to the scaled value
delay(10);                               //delay 10 ms
}
// Analog reading from two FSRs'
fsrTwo= analogRead(A1);                  //reads the fsrTwo value in A1 port
while(fsrTwo>=20)
{
servoGrip.write(0);
fsr2=fsrTwo;
break;
}
Serial.print("A1 = ");                   //prints 'A1='
Serial.println(fsr2);                    //prints the fsr2 value
 //Grip the_object
 //servoGrip.write(0);
for(pos = 0; pos<= 120; pos += .25)
{
fsrOne= analogRead(A0);                  //reads the fsrOne value
fsrOne= 1.2*(fsrOne);                    //taking μ=.6 tally the w=2μR eq.
if(fsrOne<fsr2)
{
servoGrip.write(pos);
delay(20);                               //delay 20 ms
}
}
Serial.print("A0 = ");
Serial.println(fsrOne);
Serial.print("1.2 * A0 = ");
Serial.println(fsr1);
Serial.println(".....");
delay(1);                                //delay 1 ms
}
```

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Thermochromic Property of Dichromate in Liquid Nitrogen

Dhrubojyoti Chattopadhyay

Abstract

Thermochromism is the reversible colour change of a compound when it is heated or cooled. The thermochromic colour change is distinguished by being quite noticeable, often dramatic and occurring over a small or sharp time interval. It is one of the important phenomena as it has bright future for industrial and practical use. North Bengal Science Centre regularly conducts liquid nitrogen shows for the public to demonstrate the behavior of materials at low temperatures. During the course of such shows it was observed that Ammonium dichromate exhibited thermochromic property at liquid nitrogen temperature possibly because of change in the band gap.

What is Chromism?

Chromophore is a group of atoms within a larger molecule which are principally responsible for the absorption of visible light to give the compound its colour. The colour observed is due to the visible light that is transmitted or reflected by the chromogen. Chromogenic materials change colour in response to electrical, optical (light intensity), thermal changes or with the changes of pH of the solvent. This property of materials is known as Chromism. Accordingly we can categories the chromogenic materials as follows.

Electro-chromic Materials

One of the most useful forms of chromism is electrochromism. This is displayed by the materials which change their colour or opacity with the passage of an electric current or by the presence of a strong electric field. In scientific terms, an electrochromic material is able to reversibly change its colour when it is placed in a different electronic state. So by absorbing an electron (the material concerned is reduced) or by ejecting one (the material is oxidised), it is able to change its colour.

Electrochromism was discovered in 1968 by S. K. Deb and J. A. Chopoorian and has a broad range of commercial applications. Some of those applications are smart windows and mirrors (e.g. darkening a window to control the inlet of sunlight), active optical filters (e.g. sunglasses), displays and computer data storage devices.

Good examples of electrochromic materials are polyanilines which can be formed either by the electrochemical or chemical oxidation of aniline. Depending on the oxidation state, polyaniline can either be pale yellow or dark green/black. Other electrochromic materials that have found technological application include the viologens and polyoxotungstates. Tungsten oxide (WO3), is the main chemical used in the production of electrochromic windows or smart glass.

It is relevant to mention here that there are materials which exhibit a similar phenomenon called electroluminescence. Electroluminescent materials can produce brilliant colors when electrically stimulated. Therefore they are used for decorating buildings and for industrial and public vehicles displays e.g. of safety notices. Examples of electroluminescence are :

- Powdered Zinc Sulfide doped with Copper (producing greenish light) or Silver (producing bright blue light)
- Thin-film Zinc Sulfide doped with Manganese (producing orange-red color)
- Naturally blue diamond, which includes a trace of Boron that acts as a Dopant.
- Semiconductors containing Group III and Group V elements, such as Indium Phosphide (InP), Gallium Arsenide (GaAs), and Gallium Nitride (GaN).
- Certain organic semiconductors, such as $[Ru(bpy)3]2^{+}(PF6)2$, where bpy is 2, 2'-bipyridine

Thermo-chromic Materials

Thermochromism is the change in colour of a material with change in temperature which is reversible in nature. They can be designed to change colour at a particular temperature, which can be varied by doping

the material with other compounds. Thermochromic materials are used to make paints, inks or are mixed to molding or casting materials for different applications.

The most common thermo chromic materials are Liquid Crystals such as Cholesteryl Nonanoate or Cyanobiphenyls. Liquid crystals are used in precision applications, as their responses can be engineered to accurate temperatures, but their color range is limited by their principle of operation. Some liquid crystals are capable of displaying different colors at different temperatures. This change is dependent on selective Bragg diffraction by the crystalline structure of the material, as it changes between the low-temperature crystalline phases, through anisotropic twisted nematic phase, to the high-temperature isotropic liquid phase.

Thermochromic dyes are based on mixtures of leuco dyes with suitable other chemicals, displaying a color change (usually between the colorless leuco form and the colored form) in dependence on temperature. Thermochromic papers are used for thermal printers. Thermochromism can appear in thermoplastics, duroplastics, gels or any kind of coatings. Many inorganic compounds are thermo chromic to some extent. For example, titanium dioxide and zinc oxide are white at room temperature but change to yellow when heated. Similarly normally yellow Indium (III) Oxide darkens to yellow-brown when heated. Lead (II) Oxide exhibits a similar color change on heating. The color change is linked to changes in the electronic properties (energy levels, populations) of these materials. Inorganic compounds that exhibit phase change on heating, exhibits a more dramatic effect. This includes Cuprous mercury iodide (Cu_2HgI_4), Silver Mercury Iodide (Ag_2HgI_4), Bis(diethylammonium) tetrachlorocuprate, etc.

Photo-chromic Materials

The term photochromic is applied to materials whose transmittance to light varies with the intensity of the incident light on it. Photochromic materials reversibly change colour with change in light intensity. Light sensitive sunglasses darken in response to increased intensity of sunlight and so reducing glare e.g. when driving a car or when skiing at high altitude when the snow reflects extra light into your eyes. Light sensitive photochromic materials are used in optical memory devices.

Halo-chromic Materials

Halo-chromic materials change colour according to the pH of the solvent. One possible application is to use paints that can change colour in response to corrosion in the metal underneath them e.g. in the rusting of iron or steel the pH of the water in contact with the metal changes in pH.

Details on thermochromism

Thermochromism was investigated in 1971 at first by two New York inventors, Josh Reynolds and Maris Ambats. In 1975 they bonded liquid crystals with quartz stones and set into rings named "Mood Ring" and claimed that the ring can monitor one's state of mind. The idea that the ring indicates the wearer's mood is based on a claim that body heat fluctuates with the emotional state of the wearer. Human body temperatures are known to vary by small amounts (less than 0.5°C) when the body is fighting an infection or in excitement. But the idea became a flop as the variations in ambient air temperature appear to have a larger effect on the temperature of the ring than changes in the body temperature. However, the invention of the 'Mood Ring' stimulated scientific research. Scientists became interested to know the specific mechanisms of colour change in these materials. Following 4 materials are used in investigating thermochromism.

1. Organic Compounds
2. Inorganic Compounds
3. Polymers
4. Sol-Gels

Thermochromism in Organic Compounds

Advantages of thermochromism for these organic compounds are that their color change takes place sharply and that there are many ways to control temperature easily. It has wide applications for fiber optics, photo storage instruments, optical sensors and so on. The mechanism responsible for thermochromism varies with molecular structure. It may be due to equilibrium between two molecular species, acid-base, keto-enol, lactim-lactam, or between stereoisomers or between crystal structures.

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Thermochromism in Inorganic Compounds

Many metals and inorganic compounds are known to exhibit thermochromic behavior either as solids or in solution. It has been suggested that such thermochromic behavior arises from one of the following mechanisms :

- Phase transition
- Change in ligand geometry
- Equilibrium between different molecular structure
- Change in the number of solvent molecules in the coordination sphere
- Change in the gap between valance band and conduction band

Polymer Thermochromism

Polymer thermochromism arises from polymer planar-non-planar conformation transition. Specially, poly-acetylene is well known as polymer thermochromic material. Generally poly-acetylene can be synthesized in solid state. Color change happens due to transformation of acetylene structure to buta-triene structure.

Sol-gel Thermochromism

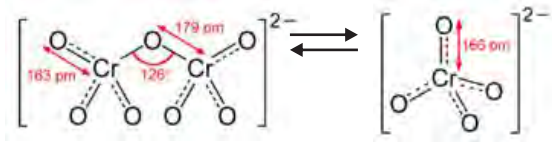
Interactions between macromolecules fall into four categories: ionic, hydrophobic, Van der Waal and hydrogen bonding. Phase transition in polymer gels provides a means of studying these interactions. Many gels will undergo reversible, discontinuous volume changes in response to changes in temperature. This transition results from the competition between repulsive intermolecular forces, usually electrostatic in nature, which act to expand the polymer network, and an attractive force that acts to shrink it.

What exactly happens to Dichromate in liquid Nitrogen ?

Ammonium dichromate is usually orange in colour as its oxidation state is +6. It is observed that if we put a test tube containing aqueous solution of Ammonium dichromate in liquid nitrogen, the color turns to yellow. The yellow state of chromium is +4 i,e, chromate. It is also observed that the reaction is reversible. On withdrawing it from liquid nitrogen the color again turns to orange after sometime.

Initially it was thought that it is a chemical reaction in aqueous solution, as chromate and dichromate anions exist in a chemical equilibrium -

$$2\ CrO_4^{2-} + 2\ H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$$



But the question is, according to Le Chatelier's Principle, at low temperature the water will freeze so we should get more dichromate than chromate ion. Ammonium chromate is also a stable compound at room temperature, so the reaction should not be a revisable one. Again we have carried out the same experiment with solid Ammonium dichromate instead of aqueous solution. The same result was obtained. In this case too, solid orange colored materials turn to yellow in low temperature and after some time it again turns in to orange when comes back to normal temperature. Not only that, if we pour liquid nitrogen directly to the solid (which means we carried out the reaction in inert medium, as nitrogen is almost inert in nature) it has shown the same behavior.

Ammonium Dichromate

Ammonium Chromate (?) or Ammonium Dichromate (Courtesy:-Wikipedia)

Therefore, the primary conclusion is that it is not a chemical phenomenon; rather it may be a physical change and the yellow substance, though looks like Ammonium Chromate, is actually Ammonium Dichromate.

To be sure that it is a physical change and not chemical one, we have taken the sample in a test tube and sealed it with grease to make it air tight. Same result was seen in

this case too. Again we have poured liquid nitrogen into the sample and sealed the test tube, so that entire change could take place in an inert atmosphere. Same experiments have been carried out with two different solvents, alcohol and acetone. In all the cases we have observed the same results. Potassium dichromate also shows a similar result. So it is confirmed that dichromate shows thermochromism at low temperature as a result of physical change.

Conclusion

It has been found by scientists that a mixture of Chromium (III) oxide and Aluminium (III) oxide in 1:9 ratio is red at room temperature and grey at 400 °C, due to changes in its crystal field. In our experiment, the dichromate compounds showed distinct colour changes when cooled. In most of the cases thermochromic behavior is shown due to phase transition or changes in ligand geometry, but here the most possible cause is due to change in energy gap between valance band and transition band or due to inner orbital electron rearrangement. However, a detailed analysis is required to confirm the hypothesis.

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Studying the Anthropogenic Impacts on Coastal Ecosystem of Digha : A Hands-on Approach

Subha Sankar Ghosh, Partha Sarathi Saha

Abstract

The paper discusses the broad anthropogenic impacts on the seashore at Digha, a popular tourist destination in the district of East Midnapore in West Bengal, and the awareness study programme undertaken by the Digha Science Centre involving school students and teachers. The goal was to engage the young students in field studies, hands-on activities and simple analytical experimentations in order to make them understand the various aspects of Digha's coastal ecosystem and the rising problem due to human activities.

Introduction

The term 'coast' or 'coastal zone' means a spatial zone where interaction of the sea and land processes occurs. The dominant factors that influence the formation of a coast are waves, currents, tides and riverine depositions. The health of a typical coast is maintained by its sediment deposition budget which is influenced by an interplay of different geomorphic units like beach, sand dune, swash, longshore current and wave refraction. But anthropogenic activities like dams on rivers, sand mining, shoreline engineering, urbanization etc. can adversely alter the sediment budget and the overall health of the shore.

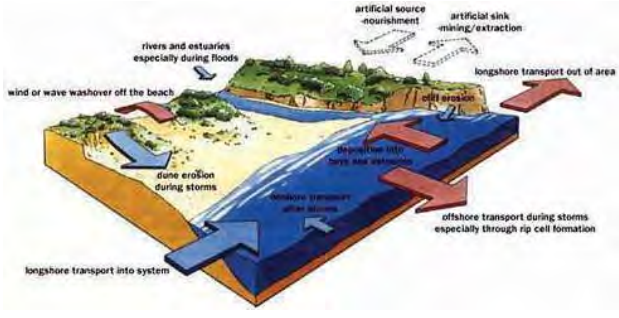

Figure 1. Sand balance of a typical seashore

The coastal environment maintains a delicate balance by the interplay of different processes like erosion, deposition, transportation and the living organisms residing in the same. The coast and its adjacent areas, on and off shore, support a rich diversity of plants, animals which are crucial to the health of the ecosystem. As every element of the food chain of an ecosystem is intertwined, their survival plays a vital role. While a high level of biodiversity has attracted humans to reside near the coasts, the various anthropogenic factors have impacted the ecosystem in a major way.

The length of India's coastline of including those of Andaman and Nicobar Islands and Lakshadweep Islands is 7517 km. These coasts support almost 30% of the total human population of India. Coasts offer economic as well as a host of recreational activities such as swimming, fishing, surfing, boating etc. As a result, a huge number of tourists are naturally attracted to these areas. This results in increasing interventions of humans on the ecosystem which lead to appreciable coast modification and environmental problems. Here we will be discussing only the broad anthropogenic impacts witnessed on the shore of Digha and the awareness programme undertaken by the Digha Science Centre.

Coast of Digha : a case study

Digha is located in the southern most part of West Bengal on the bank of Bay of Bengal. It is situated nearly mid-way along the relatively curved shoreline between the huge Ganga-Brahmaputra delta in the east and the joint Mahanadi-Brahmani-Boitaroni delta in the south west. From the geo-morphological point of view, Digha is located on the eastern fringe of the Subarnarekha basin along the south west shore line of West Bengal and on the north eastern border of Orissa.

Figure 2. Map of Digha

Impact of tourism

Digha is endowed with a nice natural flat beach and a relatively calm sea and a big fish landing station at Digha Mohna. It is well connected by rail and road to Kolkata. All these factors have played a positive role in attracting a large number of tourists throughout the year to Digha. In fact, around 35 lakhs tourists visited Digha in the FY 2012-13 alone. The ever increasing growth of tourism has resulted in a rampant growth of hotels and tourist lodges in the area. According to data published in the paper titled *'Coastal zone Management in India- An Overview'* by S Ramachandran, the percent increase of urbanization especially in the form of Hotels etc of Digha has been 1266% within a period of 10 years ie; 1988-1999. Visit of tourists on such a large scale has altered the beach characteristics considerably over the recent years. For example, the population of Olive Ridley turtles and Red Crabs that were regular visitors to Digha's coast in the past has diminished appreciably. While their absence has made the beaches less attractive, it also points to the underlying truth of ecosystem imbalance and deterioration.

Beach modification and its impacts

From a morphodynamic viewpoint, Digha's beach is erosional with a dissipative nature. Natural forces like tides with average amplitude of 4m, periodic cyclonic storms with wave height of around 7m accelerate the process. Behind the beach there are undulating sand dunes covered with halophytic vegetation. The dunes supply sand to the beach whereas the vegetation buffer protects the inland from storm surges. The rip currents and longshore currents along with the winds play a significant role in balancing the sand budget between the sand dunes and the inter-tidal zone. Unfortunately the exponential rise in construction of hotels by cutting the sand dunes has destabilized the sand supply of the beach. According to Annon (2005)[3], more than fifty five species of mangroves and eight species of phytoplankton have been recorded in this ecosystem. It is no wonder that sand binders like *Ipomea, Pandanus* and *Spinifex* and other native species like *Pandanus fascicularis, Cyperus* etc. which used to form the vegetation cover, are on their way to extinction. In addition, the construction of 5km long concrete sea wall and embankments has failed to check the erosion. Rather these structures increase the erosive strengths of waves causing beach lowering. Studies show that the average beach lowering in front of concrete wall is around 6.3 cm/year. The adjoining areas of Digha, which are not protected by sea wall experienced dune migration. Reports show that between 1877 and 1965, the beach front dune complex retreated landward by about 970 m at the rate of 11m per year due to frequent marine transgression (Bhandari and Das, 1988). Interestingly the rate of retreat has been 17.5 m per year between 1965 and 1995 after the construction of sea wall. (Paul 2002, A.K.Bhatttacharya et al, 2003)

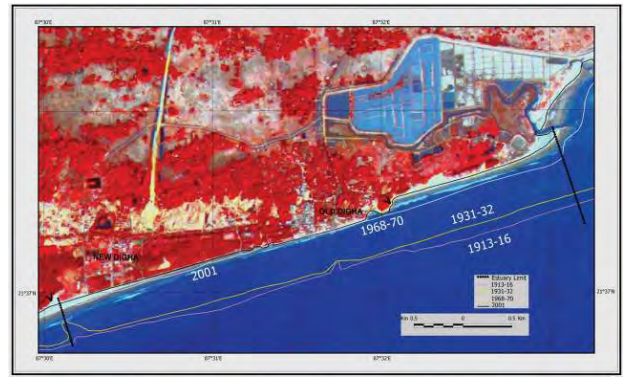

Figure 3. Evidence of coastline retreat of Digha from 1913 to 2001 (satellite imagery)

Studies have confirmed that while the total length of coast of West Bengal is around 200kms, erosion is occurring on a large stretch of 180 km of the beach (Joshi, 1995). In addition to Beach destruction, the increase in groundwater extraction by unscrupulous pumping has lead to greater sea water intrusion in the mainland leading to contamination of ground water making it saline. This was confirmed by measuring the chloride/bicarbonate ratio. According to S. Basack, A.K.Bhattacharya, & P. Maity, 2012, the specific conductivity concentration of water sample of Digha

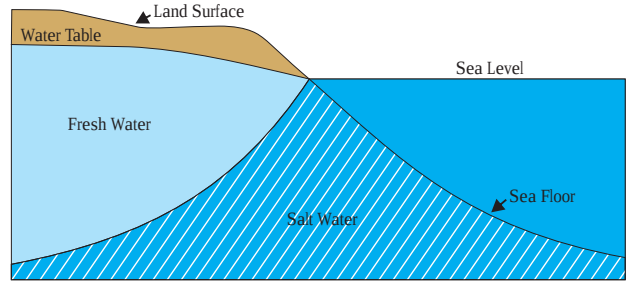

Figure 4. Salt water intrusion in freshwater (schematic illustration)

along the sea shore line is as high as 26000 micromhos/cm. It has been found that the nearby Contai town with its surrounding rural areas of 45 square miles has become a saline zone (Dr. A. K. Bhattacharya & Dr. S. Basack, 2012). This is making the groundwater unfit for drinking and other uses like irrigation.

Dumping of waste and impact on native Flora and Fauna

At present there are around 450 hotels in Digha catering to around 35 lakh tourists annually, which leads to a huge amount of waste of all kinds. Sadly there is no proper waste management system in place. As a result, all forms of waste are directly dumped into the sea without any treatment. In addition, lack of proper awareness has resulted in littering of coast with non biodegradable wastes like plastics etc. All these activities have polluted the coast as well as the sea water. As a result the native flora and fauna is getting adversely affected.

Fishing Industry

India is the 7th largest fishing nation in the world. Marine fish products contribute about 50% to the total fish production. An estimation of depth-wise potential of coastal fishery shows that about 58% of the resources are available in 0-50m depth, 35% in 50-200m depth and 7% in depths beyond 200m. (Source: Ministry of Agriculture, 2000).

Surprisingly there has been a steady decrease in the catch per unit effort (CPUE) of mechanized boat in the last five years in Digha Mohna. It was 3.26 tons per boat in 2000-01 which has gone down to 2.69 tons per boat in 2003-04. These figures are pointing to the non sustainability of fishing in this part of coast in near future. This is a real cause of concern for the future of fishing community in Digha (Source: Integrated Coastal Zone Management Project, Fisheries, Dept. of Environment, Govt. of West Bengal; http://www.iczmpwb.org/main/fisheries.php).

Most marine fishes are found within the depth of 200m and are dependent on the abundance of phytoplanktons, free floating microscopic organisms which form the base of several aquatic food webs in the ocean. These microscopic marine plants need sunlight to live and grow. But offloading of sediments from rivers into the sea is increasing the turbidity level of marine water thereby affecting the availability of sunlight for the phytoplanktons to survive. The major rivers of the Bay of Bengal drain 200 km^3 of water and 12.0 x 10^9 tons of silt during the monsoon season. Sediment deposition of this proportion increases the turbidity of water considerably. As a result, sunlight cannot penetrate to greater depths and hence reduce the phytoplankton population. This ultimately results in the decrease in fish production. Studies show that indiscriminate deforestation, construction, industrialization along the rivers is destabilizing the river banks which are increasing the level of siltation.

Overfishing to meet the ever increasing demand is also altering the overall balance of the marine ecosystem. According to Digha's local fishermen, there has been a severe decrease in the catch of *Hilsa* in this area. Moreover there has been a marked change of fish population diversity from multi species to single species with predominance of marine catfish at Digha.

The shells of the mollusks which usually dominate any beach are not seen in this area. The reason behind their disappearance is their rampant harvesting for use in poultry industry as feed. To study various anthropogenic impacts on Digha, regular studies are being conducted by different organizations. In general it has been found that there has been an appreciable decline in biodiversity richness because of several anthropogenic factors like using different types of nets which is causing death by entanglement of large fauna like turtles in fishing nets and by ingestion of marine debris etc. In addition, coastal constructions like sea walls, jetties and hotels, increase in beach littering, clearing of stabilizing vegetation of the dunes, sand compaction due to driving of vehicles on beach, beach erosion, environmental contaminants from sewage, agricultural runoffs, non biodegradable wastes etc. are causing a decline of native floral and faunal population.

Immediate steps need to be taken to save this fragile ecosystem from total destruction. This calls for a sustained awareness campaign among the local population as their cooperation is vital for carrying out restoration activities. With this in mind, Digha Science Centre, a unit of the National Council of Science Museums, has started working with the local students and teachers for creating awareness about the

seriousness of the issue and prompting corrective actions by the stakeholders. The Science Centre has launched a field study cum awareness campaign which involves field trips, sample collection, analytical experimentation and discussion with experts for a scientific understanding of Digha's deteriorating marine ecosystem and for motivating them to work for a solution in the future.

Overview of the activities

Hands on science involve integration of instructional science education and activity-based learning through direct experience with nature. This programme is a form of active learning which involves students to make observations of nature and learn from the observations through critical analysis of gathered facts and figures.

During the last two years (2012-13 and 2013-14), Digha Science Centre organized four field trips and activity camps related to the practical study of marine biodiversity in and around Digha. A total of 214 students and 36 teachers from 33 schools participated in these programmes in 4 batches. These were essentially residential camps with the participants staying inside the science center campus for 3 days and performing a number of activities. While the daytime was used for field trips, associated activities and experimentations, the evenings were scheduled for discussions and interactions with the experts. Extensive field works were conducted in two locations, which were selected on the basis of the level of anthropogenic disturbance of the marine ecosystem in these locations. At every location, similar set of experiments were carried out at four distinct zones, as shown below. This helped comparison of collected data on real time basis.

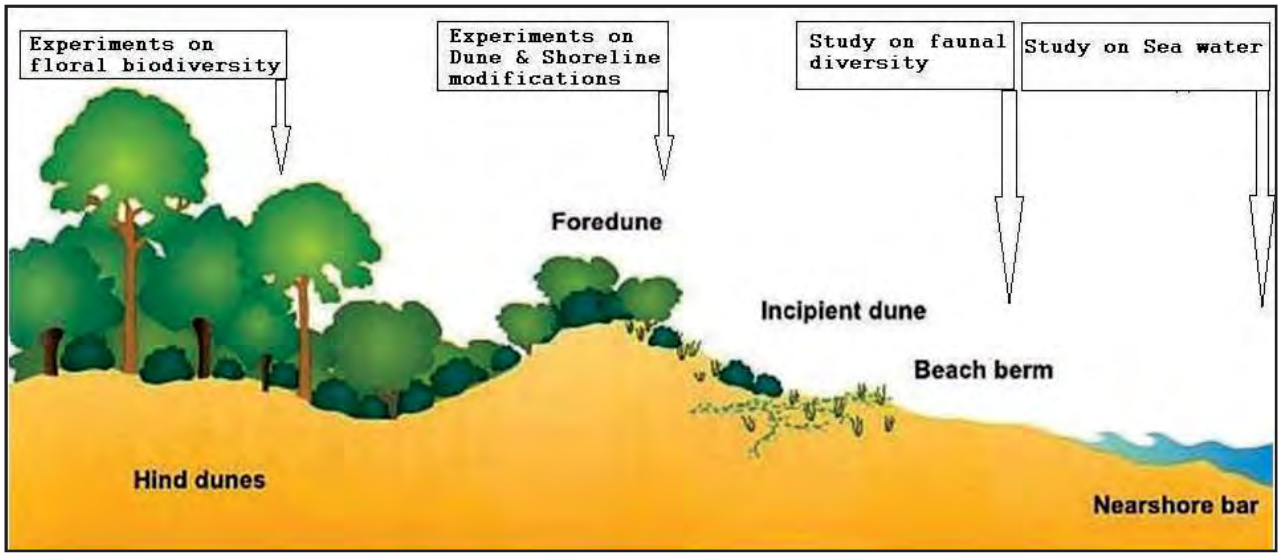

Figure 5. High anthropogenic disturbance (Site A)

Relatively Undisturbed (Site B)

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Examples of hands-on experiments conducted

a) Determining the Species Biodiversity Importance Value Index (IVi)

This activity was done to assess the flora in the hind dune zone. The index gives an overall estimate of the influence of a plant species in a community. It helps to determine the degree of disturbance of an area by assessing the importance of the invasive species at a given site. Higher IVi for invasive species clearly points to the effect of anthropogenic factors like habitat fragmentation or alteration, change in nutrient status due to application of fertilizers, increase or decrease in humidity, introduction of new plants etc.

This index was calculated by determining the parameters like Abundance, Relative Frequency and Relative Density of the species in the site.

Procedure followed

To determine the above parameters, an area of approximately 500 m was selected in both the sites. Thereafter students were taken on a field trip to identify the major plants present there. This was followed by making Random Quadrates of 1m x 1m, and it is

Figure 6a. Floral identification

Figure 6b. Analyzing a Quadrate

evident from the above results that the site which is heavily disturbed is showing a decrease of IVi for the native species like Pandanus (Keya), Calotropis (Akanda) etc. On the other hand, a disturbing trend was noticed during the field trip where a relative dominance of invasive plants like Parthenium, Lantana camara etc are found. Such trends were not found in the undisturbed site where a relative dominance of halophytes was noticed.

Results :

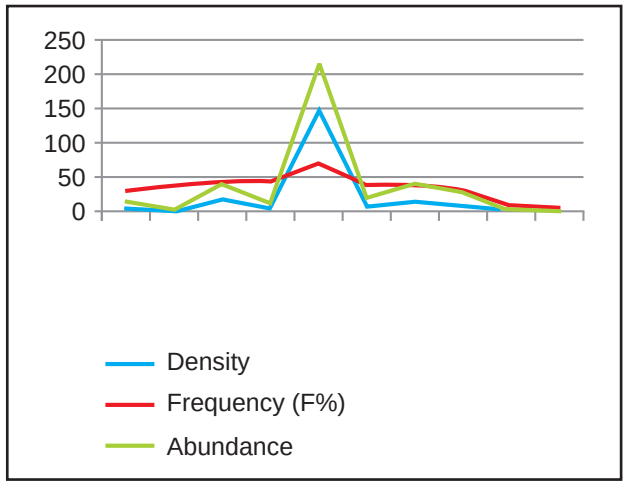

Figure 7a. Floral distribution in less disturbed site

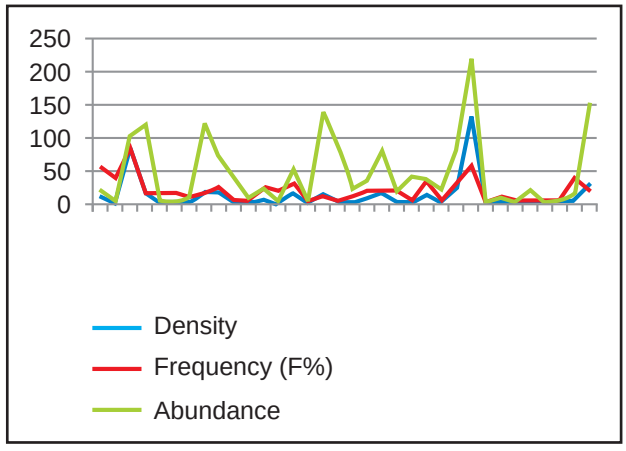

Figure 7b. Floral distribution in heavily disturbed site

Figure 8a. Studying sand dune vegetation

Figure 8b. Floral identification session

b) Determining the habitat distribution of crabs

According to a study (S. Ravichandran et al 2001) on the mangrove swamp of Pichavaram, around 23 species of crabs were found. Similarly the campers observed different species of crabs on the shore of Digha and adjoining areas too. The important ones among them are *Dotilla, Metaplex, Uca, Ocypode* etc. Scientists opine that crabs play an important role in nutrient cycling of coastal ecosystem. As such there presence and richness is a good indicator of the health of a beach.

Burrows of crabs in the sands of seashores are a common experience. Interestingly the burrow openings are different for different species. Most of them were found to be surrounded by sand balls in different fashions. These balls were made by crabs after eating all the microscopic edible stuff present in it. The unique burrow architectures represent a complex system that houses many types of beneficial micro organisms. Some of these microbes are reported to play a beneficial role in nitrogen cycling.

Figure 9. Study of crab habitat by Quadrate Method

Figure 10. Field trip of teachers on shoreline engineering

The students were introduced to this macrofauna by studying the burrow distribution along the coast. This was done by making Random designed quadrates of 3ft x 3ft, from low tide level to the dune.

Employing the Quadrate Method, the different parameters that were studied are :

a) Distribution of different species of crab in relation to tide level
b) Distribution of different species of crab in relation to nutrient distribution on the shore
c) Effect of concrete embankment on crab community
d) Comparing species richness at contrasting sites
e) Comparing hole architecture of crabs at contrasting sites

Equipments /material used : Lux Meter, Vernier Caliper, Plaster of Paris

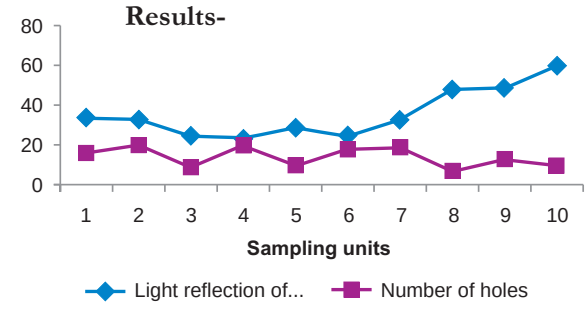

Figure 11. Distribution of crab hole vs. organic content as determined by light reflection

No of S.U	Big hole	Small hole
S.U - 1	0	4
S.U - 2	0	3
S.U - 3	0	5
S.U - 4	0	9
S.U - 5	0	6
S.U - 6	0	8
S.U - 7	0	18
S.U - 8	0	50
S.U - 9	0	52

Table : A

of S.U	Big hole	Small hole
S.U - 1	0	22
S.U - 2	0	31
S.U - 3	0	46
S.U - 4	0	249
S.U - 6	0	278
S.U - 7	0	191
S.U - 9	5	0
S.U - 9	2	120

Table : B

Figure 12. Distribution of crab hole in relation to presence of concrete embankments (Table A) and in absence of concrete embankments (Table B)

Based on the results obtained by conducting all these experiments, it could be concluded that different species of crabs inhabit different zones on the beach. But anthropogenic disturbances like sand compaction, presence of sea wall, destruction of sand dune etc. seem to adversely influence the richness of crab species as well as their burrow architecture and possibly their survival.

c) Assessing the health of the sea water

The health of the sea water is vital for the survival of the organisms living in it. As such when this water is exposed to various kinds of pollutants like untreated wastes, oil spills etc., it makes the condition inhospitable for marine organisms.

A number of tests were conducted to check the quality of seawater near Digha coast. In addition, salinity of this water was also tested so that the effect of fresh water from different rivers like Hooghly, Subarnarekha could be assessed.

Procedure

Water samples were collected from two sites; one from the mouth of the drain that dumps water directly into sea and the other where no such drains exist. Thereafter the following experiments were conducted. The results were tabulated by taking average of three observations from each experiment.

Determining the pH of the water sample

This experiment was done by two methods. At first pH strips were used and the results so obtained were rechecked using digital pH meter. Results showed that the pH of the waste water is slightly alkaline (pH 8) whereas that of sea water is almost neutral (pH 7.1). The alkalinity of the sample indicates the probable presence of soaps and detergent in it.

Determining the salinity of the water sample

The salinity of the sample was tested using Refractometer and Digital salinometer. Interestingly the sample showed much lesser salinity (18-20 parts per thousand) as compared to the standard (36 parts per thousand). This deviation could be attributed to the mixing of fresh water from rivers in this area.

Measuring the Dissolved Oxygen content

Dissolved Oxygen (DO) in water gives an indication of the overall health of the water sample as this oxygen is used by the organisms living in it. A low value indicates the phenomenon of pollution and Eutrophication.

It was seen that while the DO of the sea water is 8-9mg/l, it is almost 6 mg/l for the wastewater sample.

Measuring the water temperature and ambient air temperature
Variation in water temperature at two sites with a constant air temperature can be interpreted as a good indicator of some inherent disturbance. If the temperature of one sample is appreciably high as compared to other, it may indicate some kind of exothermic reaction in the sample. In the samples studied, we have not found large variation.

Studying planktons
Planktons are microscopic organisms which forms the base of the food chain. Photosynthetic planktons or phytoplankton harvest solar energy and supply the same to the higher trophic levels. In general planktons support commercially important fishes and biogeochemical cycles like carbon cycle. Studies show that anthropogenic stress like nutrient offloading from rivers and agricultural run offs, influx of wastewater etc. During the camp, students collected and observed planktons from sea water, under the microscope. This was done to introduce them to the wonderful world of planktons and motivate them to take up serious studies on it in future.

Conclusion

The camp activities and the hands-on experiments were designed to cover important aspects of the local coastal ecosystem in different sites and the results from contrasting sites were tallied. From the results so obtained, it became evident to the camp participants that the coastal ecosystem of Digha is facing grave challenges due to heavy anthropogenic intervention. Steps to safeguard the ecosystem were also discussed and the steps like plantation of native species, proper management of wastewater before dumping into sea, rethinking on different kinds of shoreline engineering methods, restrictions on beach driving, protection of existing sand dunes etc. were suggested.

Participating students were surveyed through questionnaires before and after the camps to assess the impact of the camp activities on them. Results of the surveys showed an appreciable increase in their power of observation and interest level for basic science. It was observed that the field studies conducted by them in the camps inspired them for scientific research on these topics in the future. Moreover, a very positive feedback was also received from the teachers as well.

Based on these positive feedbacks from the teachers and the students, more of such camps are being planned for the future too.

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